US011105537B2

(12) **United States Patent**
Matsuda et al.

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(45) **Date of Patent: Aug. 31, 2021**

(54) **REFRIGERATION CYCLE APPARATUS**

(71) Applicant: **Mitsubishi Electric Corporation**, Tokyo (JP)

(72) Inventors: **Hirofumi Matsuda**, Tokyo (JP); **Satoru Yanachi**, Tokyo (JP)

(73) Assignee: **Mitsubishi Electric Corporation**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 140 days.

(21) Appl. No.: **16/325,203**

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§ 371 (c)(1),
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F25B 1/04 (2006.01)
F25B 43/02 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***F25B 1/04*** (2013.01); ***F25B 31/004*** (2013.01); ***F25B 43/02*** (2013.01); ***F25B 49/02*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC F25B 1/04; F25B 31/004; F25B 43/02; F25B 2400/02; F25B 2400/23;
(Continued)

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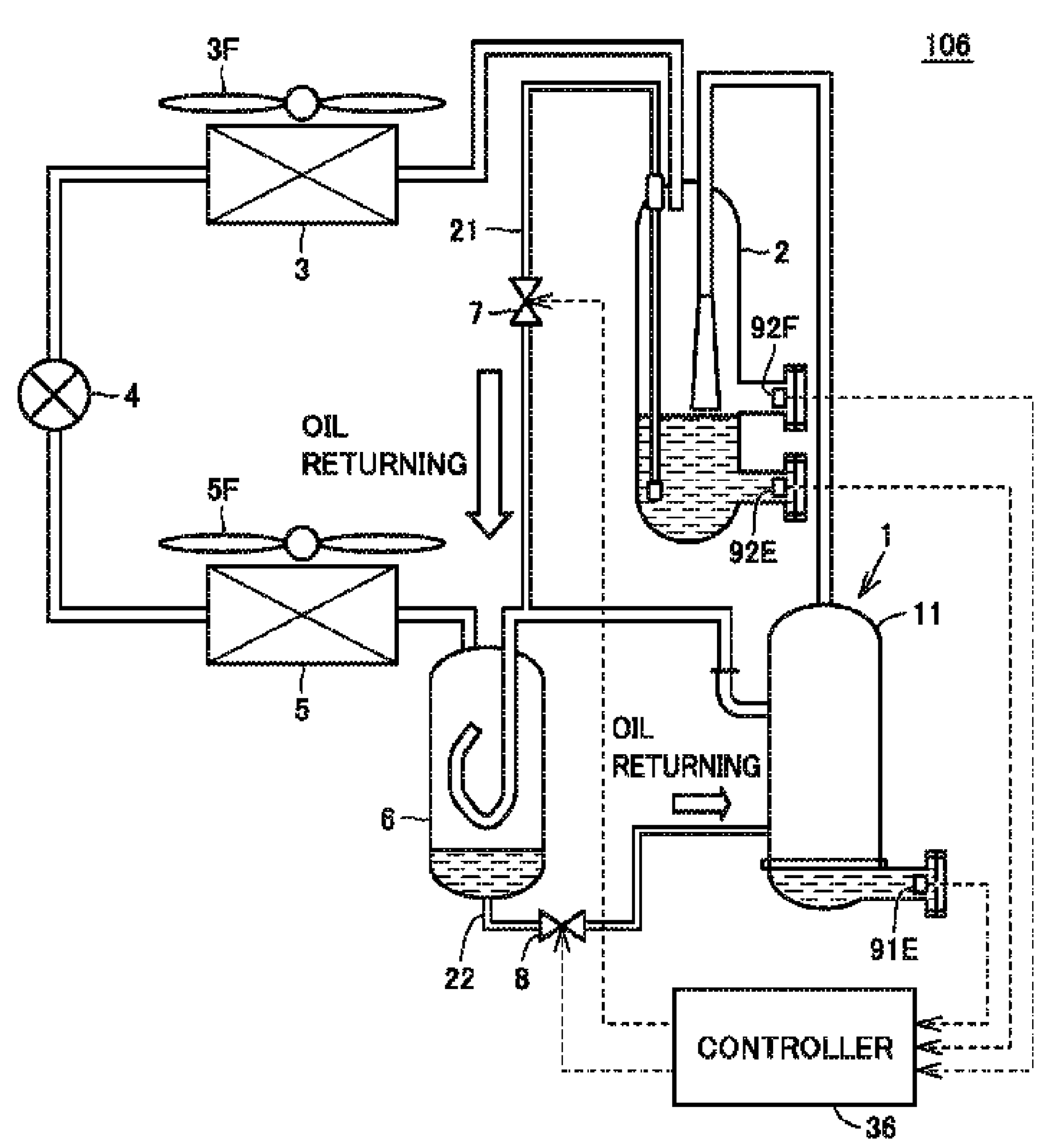
(Continued)

Primary Examiner — Joseph F Trpisovsky
(74) *Attorney, Agent, or Firm* — Posz Law Group, PLC

(57) **ABSTRACT**

A refrigeration cycle apparatus refrigeration cycle apparatus in which refrigerant circulates in an order of a compressor, an oil separator, a condenser, an expansion valve, an evaporator, and an accumulator. The refrigeration cycle apparatus includes: an oil returning path extending from the oil separator to the compressor; a first electromagnetic valve provided on the oil returning path; an oil returning path extending from the accumulator to the compressor; a second electromagnetic valve provided on the oil returning path; and a controller configured to control a degree of opening of the first electromagnetic valve and a degree of opening of the second electromagnetic valve.

3 Claims, 25 Drawing Sheets



(51) **Int. Cl.**
F25B 49/02 (2006.01)
F25B 31/00 (2006.01)

(52) **U.S. Cl.**
CPC *F25B 2400/02* (2013.01); *F25B 2400/23* (2013.01); *F25B 2500/16* (2013.01); *F25B 2600/2519* (2013.01); *F25B 2700/03* (2013.01)

(58) **Field of Classification Search**
CPC F25B 2700/03; F25B 2500/16; F25B 2600/2519; F25B 49/02
See application file for complete search history.

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Office Action dated Feb. 10, 2021 issued in corresponding CN patent application No. 201680089837.5 (and English translation).
Office Action dated Jul. 1, 2021, issued in corresponding CN Patent Application No. 201680089837.5 (and English Machine Translation).

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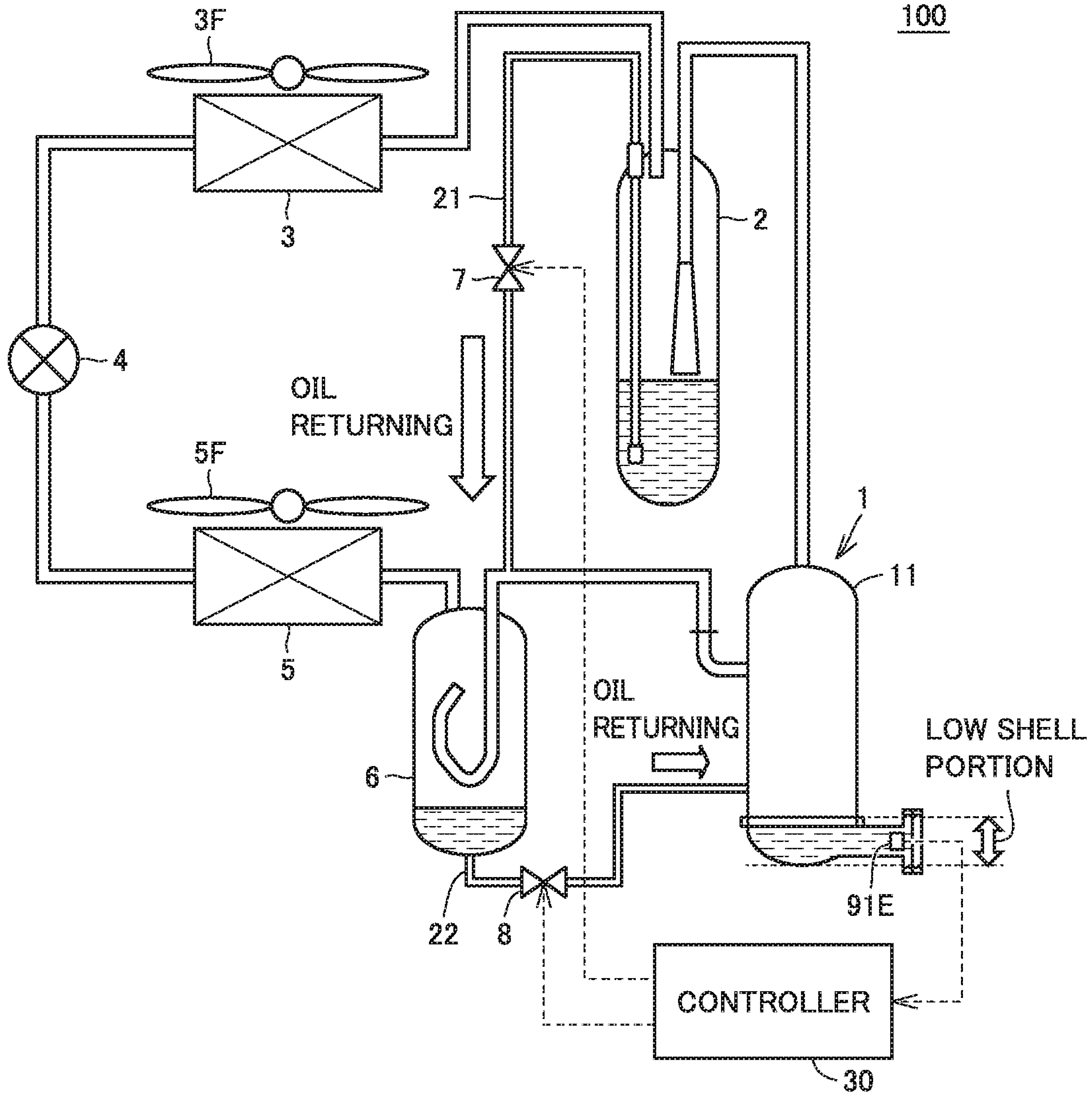
FIG.1



3F
100
21
2
3
7
4
OIL RETURNING
5F
1
11
5
OIL RETURNING
LOW SHELL PORTION
6
91E
22
8
CONTROLLER
30

FIG.2

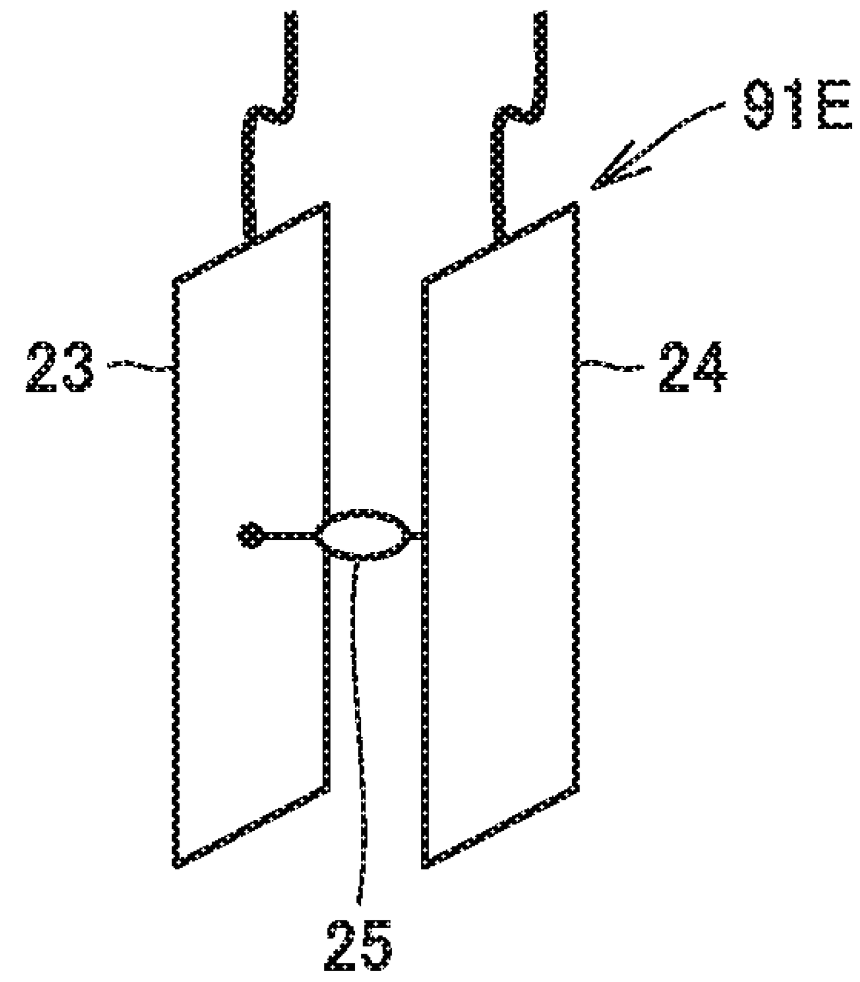

91E
23
24
25

FIG.3

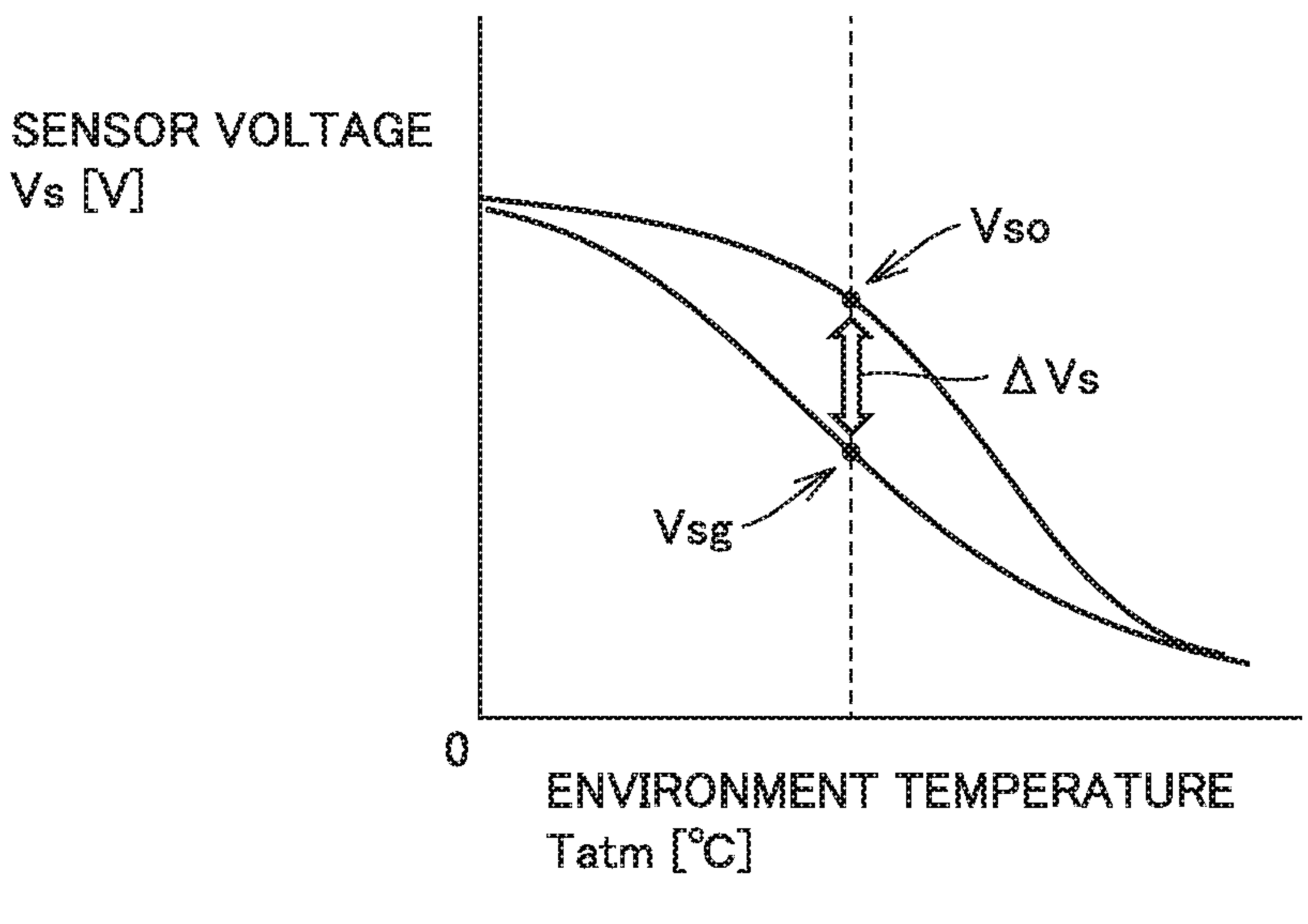

SENSOR VOLTAGE
Vs [V]
Vso
ΔVs
Vsg
0
ENVIRONMENT TEMPERATURE
Tatm [°C]

FIG.4

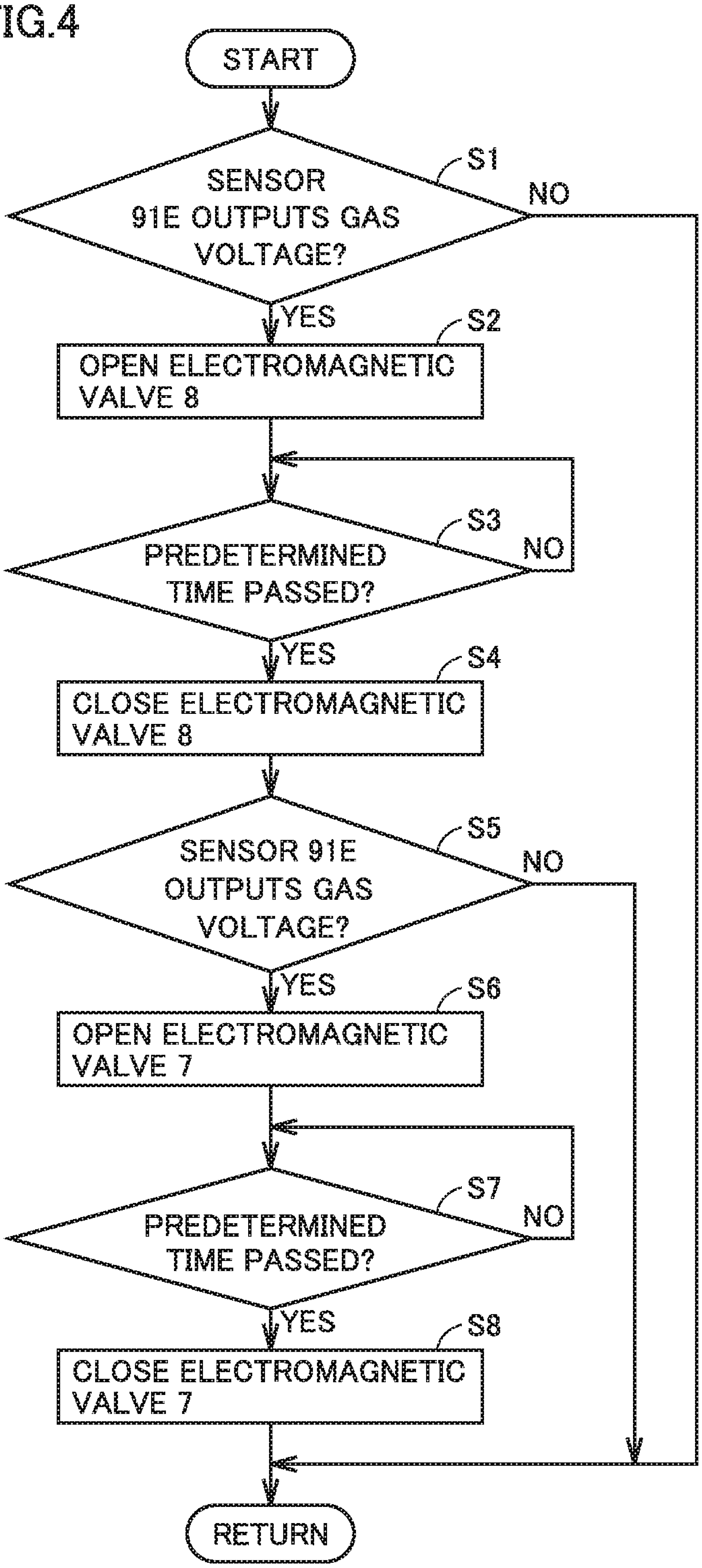

START
SENSOR 91E OUTPUTS GAS VOLTAGE?
S1
NO
YES
S2
OPEN ELECTROMAGNETIC VALVE 8
PREDETERMINED TIME PASSED?
S3
NO
YES
S4
CLOSE ELECTROMAGNETIC VALVE 8
SENSOR 91E OUTPUTS GAS VOLTAGE?
S5
NO
YES
S6
OPEN ELECTROMAGNETIC VALVE 7
PREDETERMINED TIME PASSED?
S7
NO
YES
S8
CLOSE ELECTROMAGNETIC VALVE 7
RETURN

FIG.5

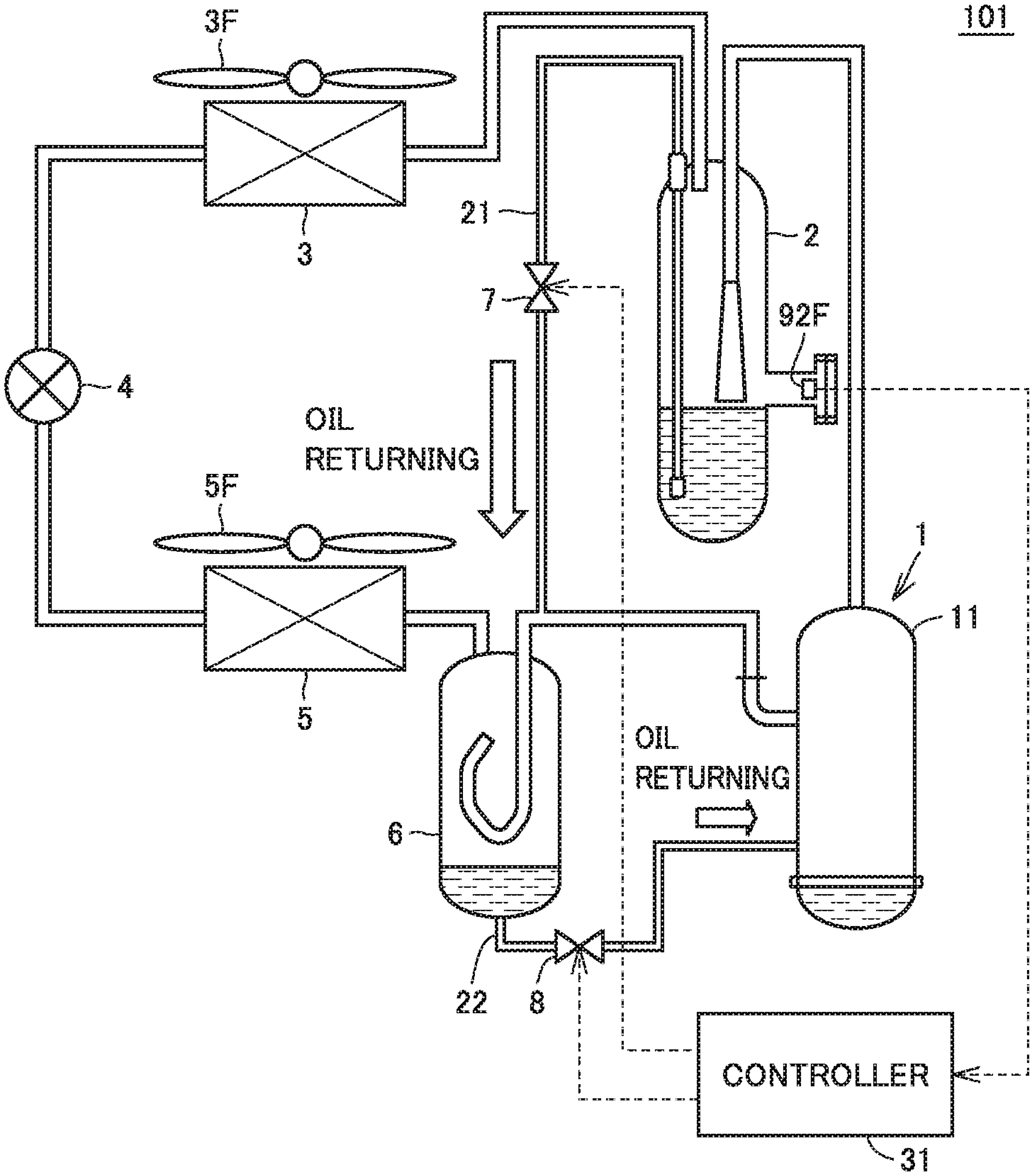

101
3F
3
21
2
7
92F
4
OIL
RETURNING
5F
1
11
5
OIL
RETURNING
6
22
8
CONTROLLER
31

FIG.6

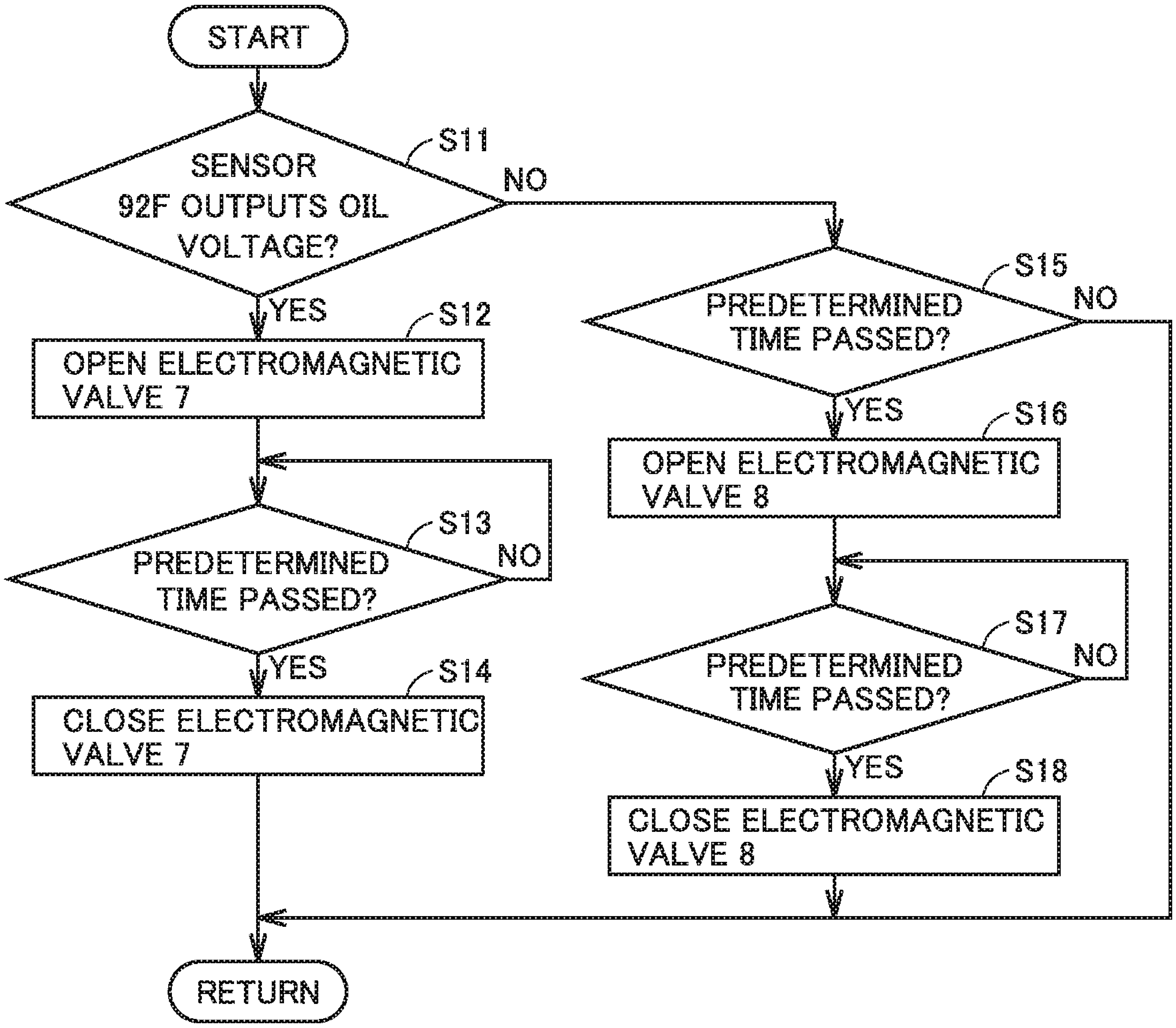

START
SENSOR 92F OUTPUTS OIL VOLTAGE?
S11
NO
YES
S12
OPEN ELECTROMAGNETIC VALVE 7
PREDETERMINED TIME PASSED?
S13
NO
YES
S14
CLOSE ELECTROMAGNETIC VALVE 7
PREDETERMINED TIME PASSED?
S15
NO
YES
S16
OPEN ELECTROMAGNETIC VALVE 8
PREDETERMINED TIME PASSED?
S17
NO
YES
S18
CLOSE ELECTROMAGNETIC VALVE 8
RETURN

FIG.7

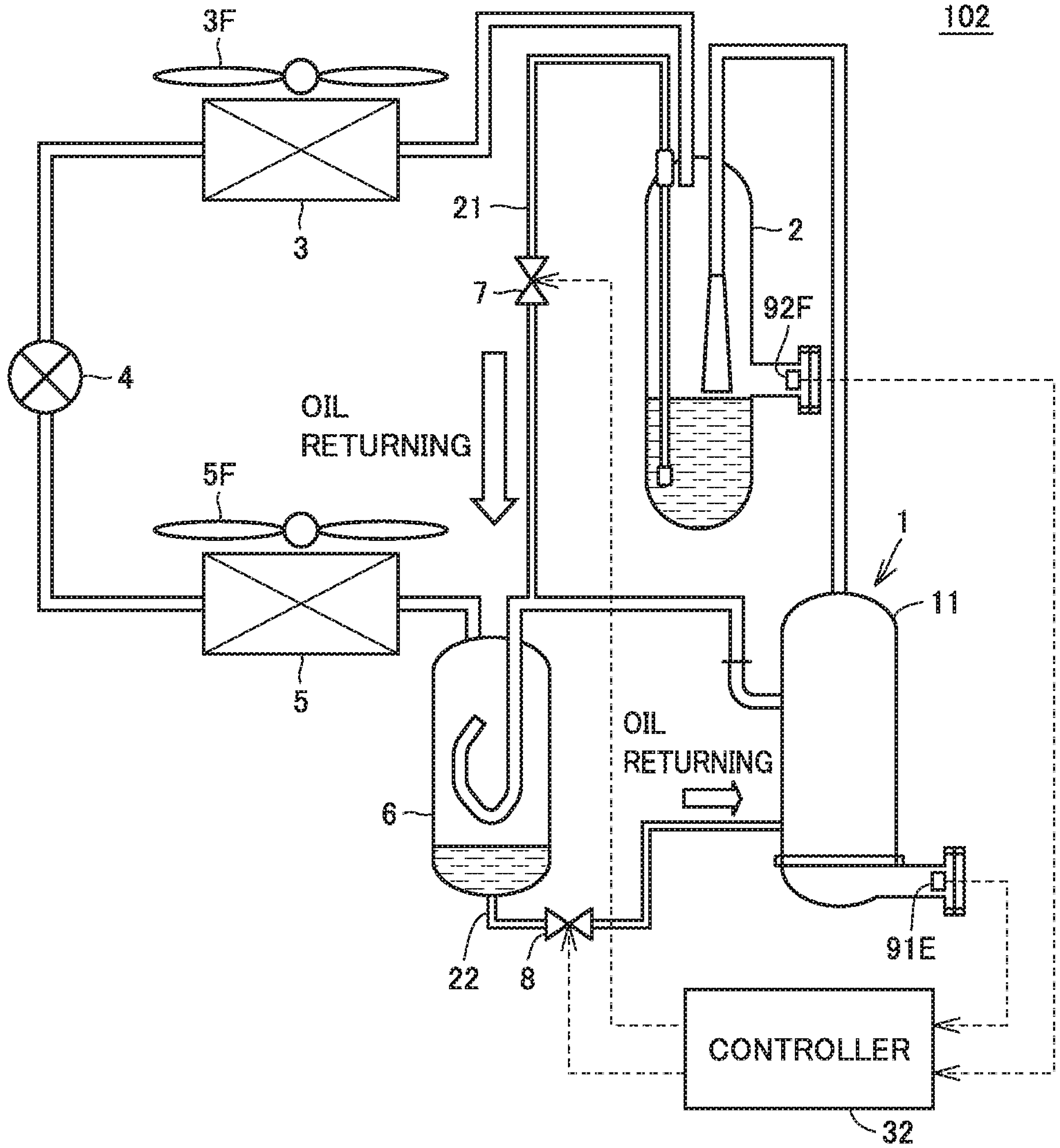

102
3F
3
21
2
7
92F
4
OIL
RETURNING
5F
1
11
5
6
OIL
RETURNING
22
8
91E
CONTROLLER
32

FIG.8

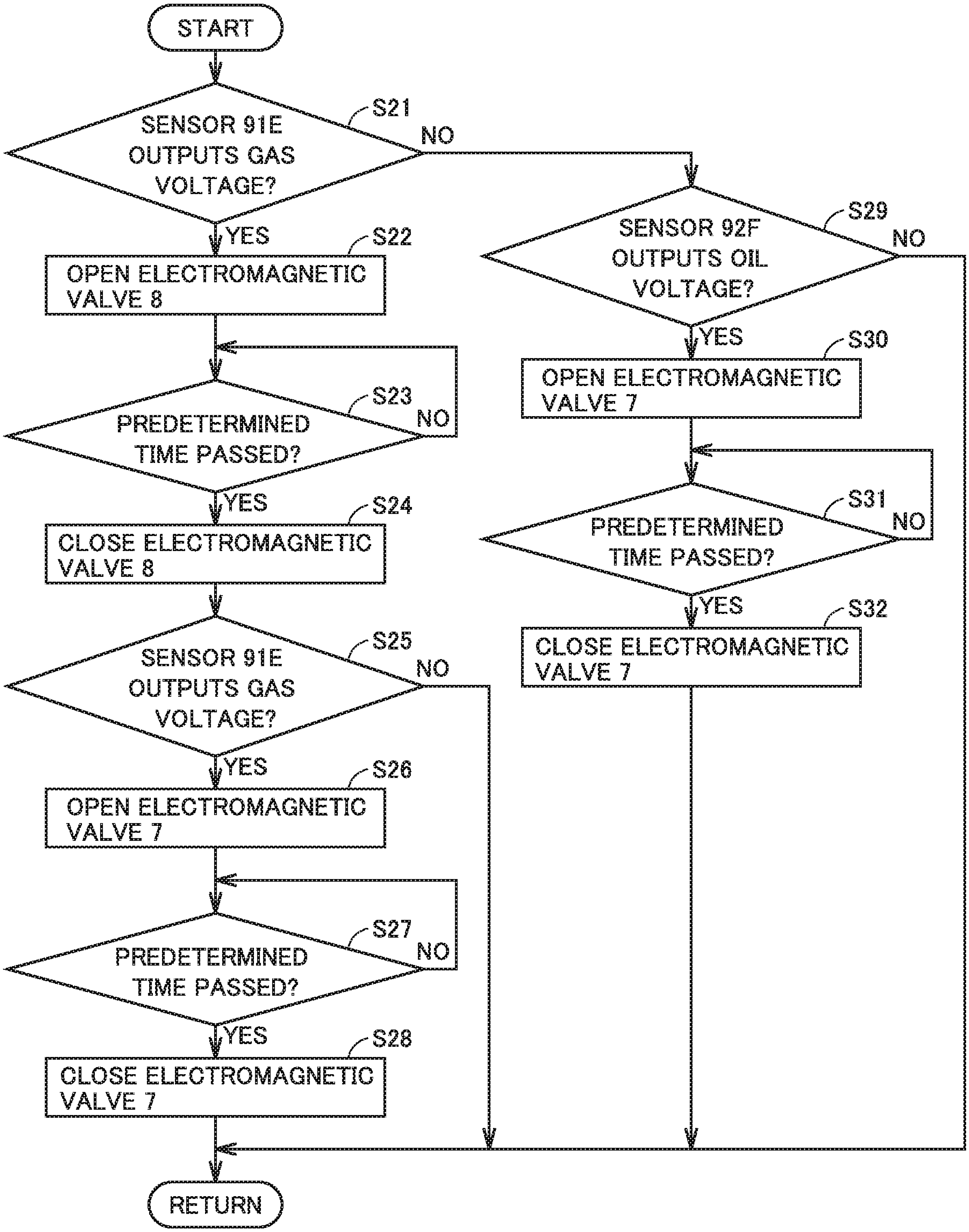

START
SENSOR 91E OUTPUTS GAS VOLTAGE?
S21
NO
YES
OPEN ELECTROMAGNETIC VALVE 8
S22
PREDETERMINED TIME PASSED?
S23
NO
YES
CLOSE ELECTROMAGNETIC VALVE 8
S24
SENSOR 91E OUTPUTS GAS VOLTAGE?
S25
NO
YES
OPEN ELECTROMAGNETIC VALVE 7
S26
PREDETERMINED TIME PASSED?
S27
NO
YES
CLOSE ELECTROMAGNETIC VALVE 7
S28
SENSOR 92F OUTPUTS OIL VOLTAGE?
S29
NO
YES
OPEN ELECTROMAGNETIC VALVE 7
S30
PREDETERMINED TIME PASSED?
S31
NO
YES
CLOSE ELECTROMAGNETIC VALVE 7
S32
RETURN

FIG.9

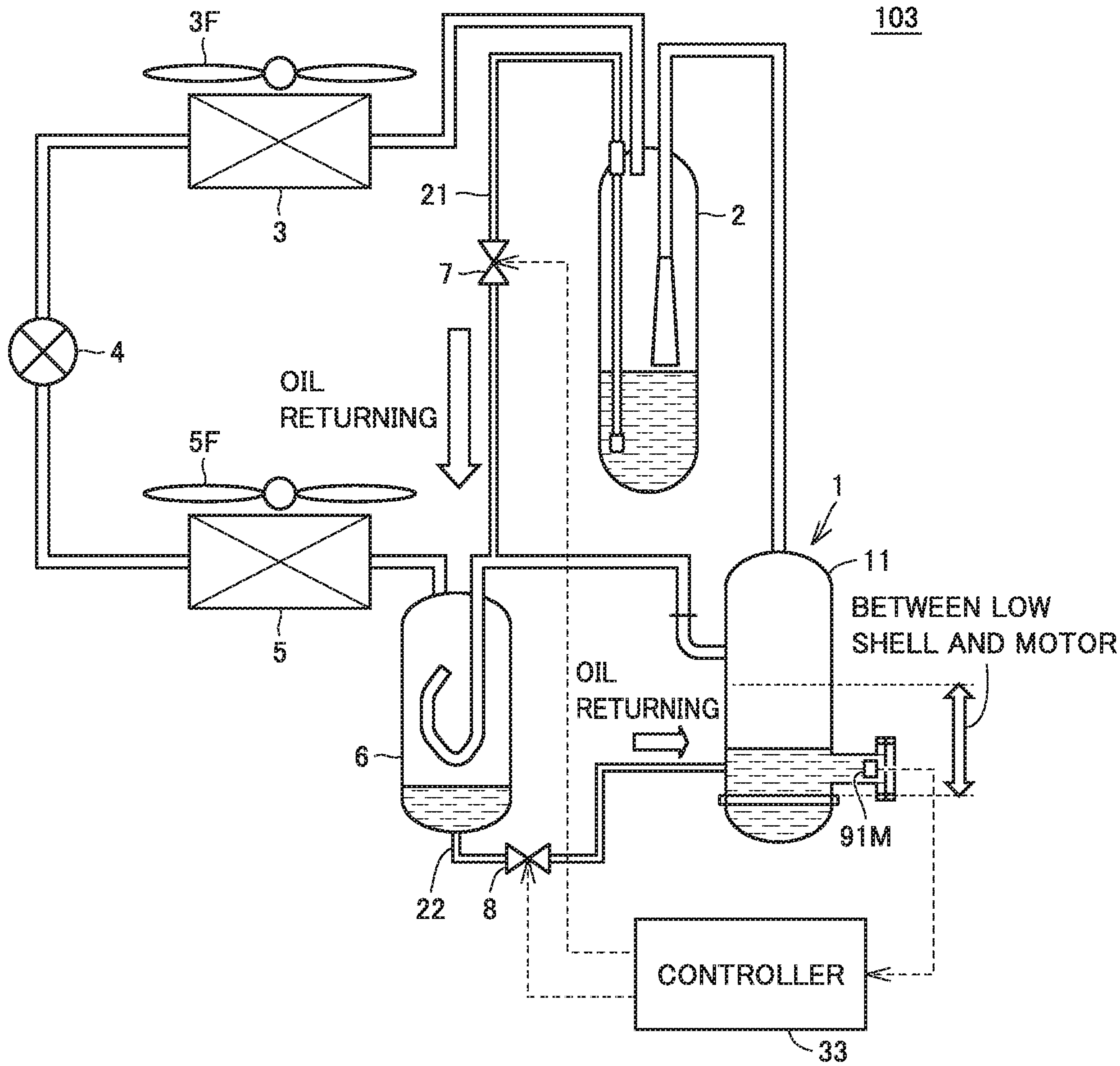

103
3F
3
21
2
7
4
OIL
RETURNING
5F
1
11
BETWEEN LOW
SHELL AND MOTOR
5
OIL
RETURNING
6
91M
22
8
CONTROLLER
33

FIG.10

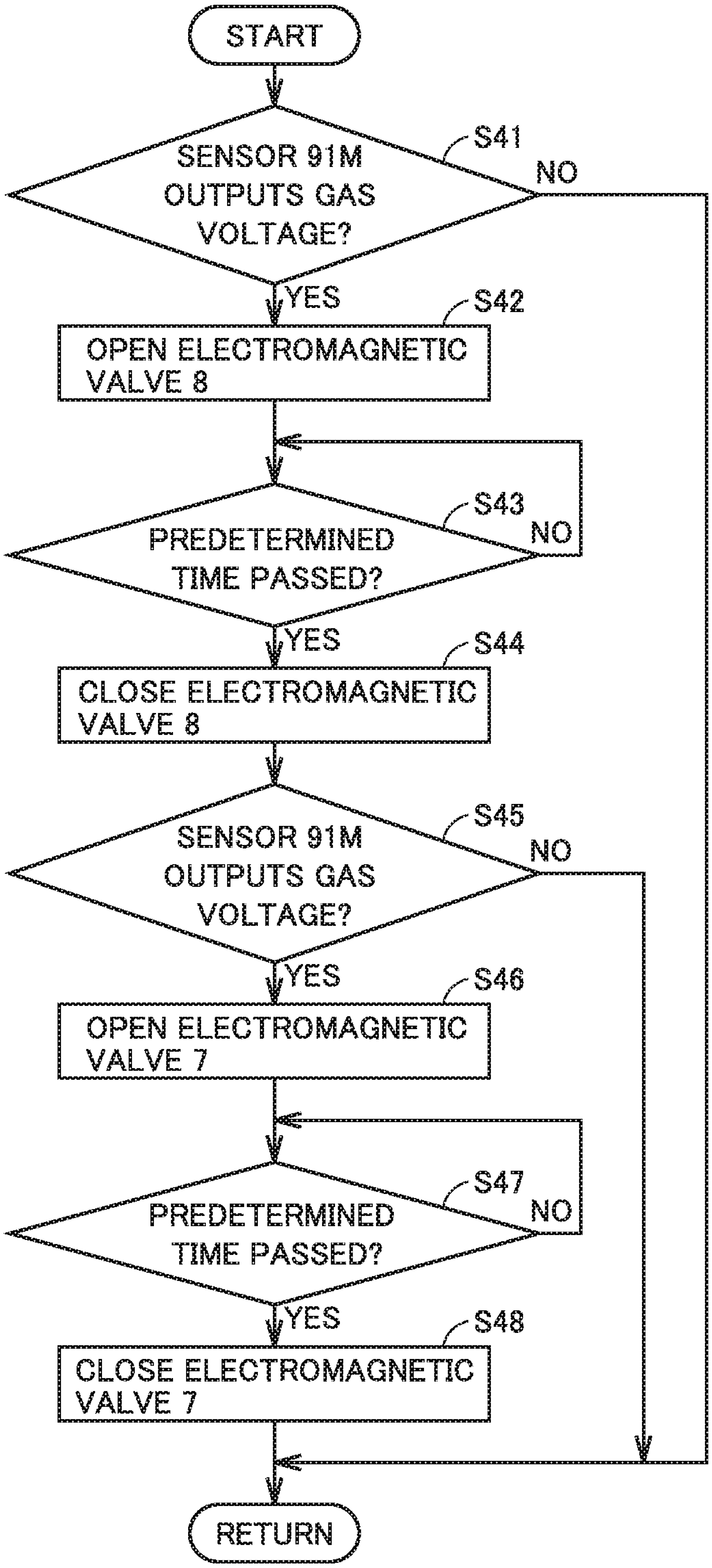

START
SENSOR 91M OUTPUTS GAS VOLTAGE?
S41
NO
YES
S42
OPEN ELECTROMAGNETIC VALVE 8
PREDETERMINED TIME PASSED?
S43
NO
YES
S44
CLOSE ELECTROMAGNETIC VALVE 8
SENSOR 91M OUTPUTS GAS VOLTAGE?
S45
NO
YES
S46
OPEN ELECTROMAGNETIC VALVE 7
PREDETERMINED TIME PASSED?
S47
NO
YES
S48
CLOSE ELECTROMAGNETIC VALVE 7
RETURN

FIG.11

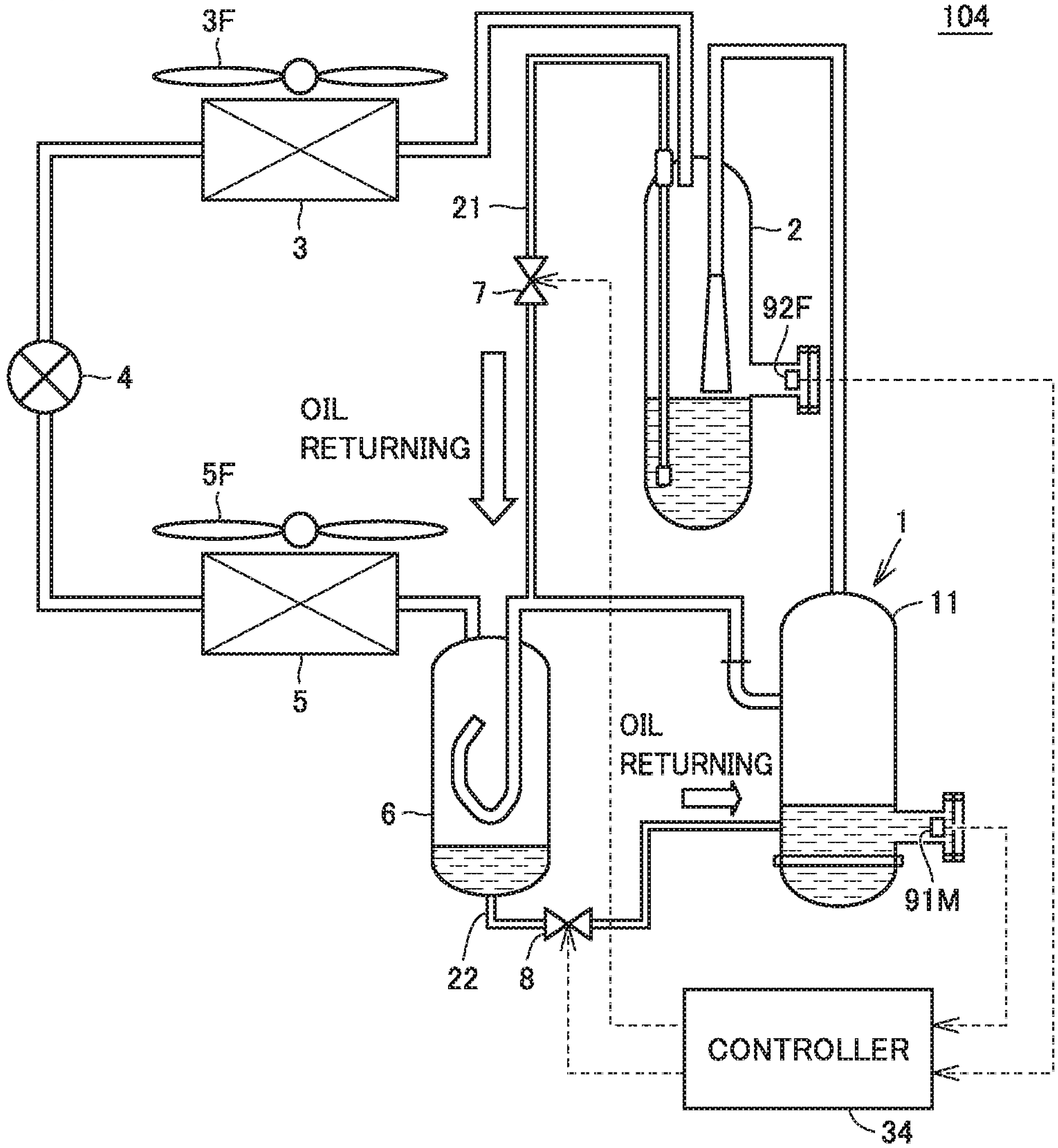

104
3F
3
21
7
2
92F
4
OIL
RETURNING
5F
5
1
11
6
OIL
RETURNING
91M
22
8
CONTROLLER
34

FIG.12

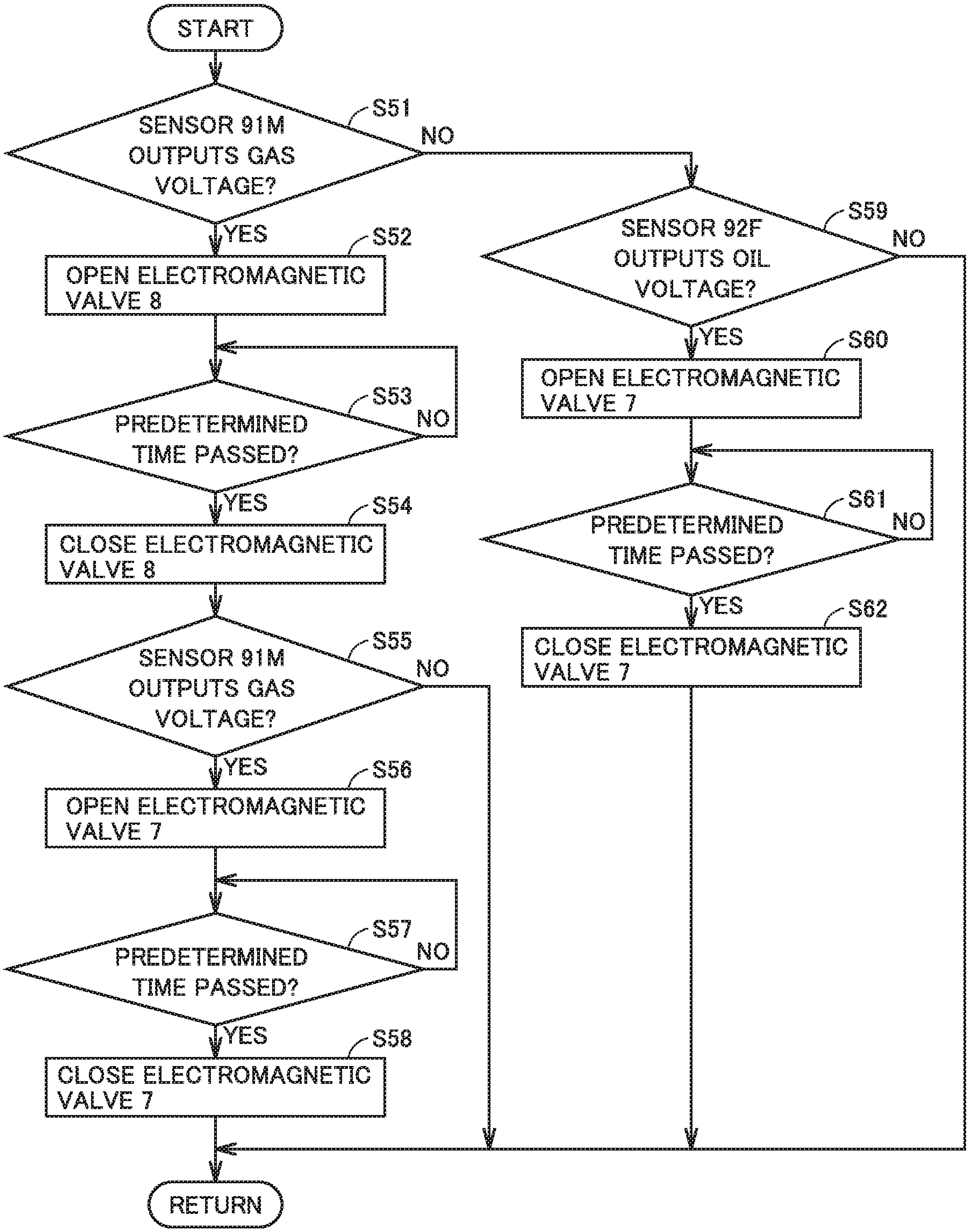
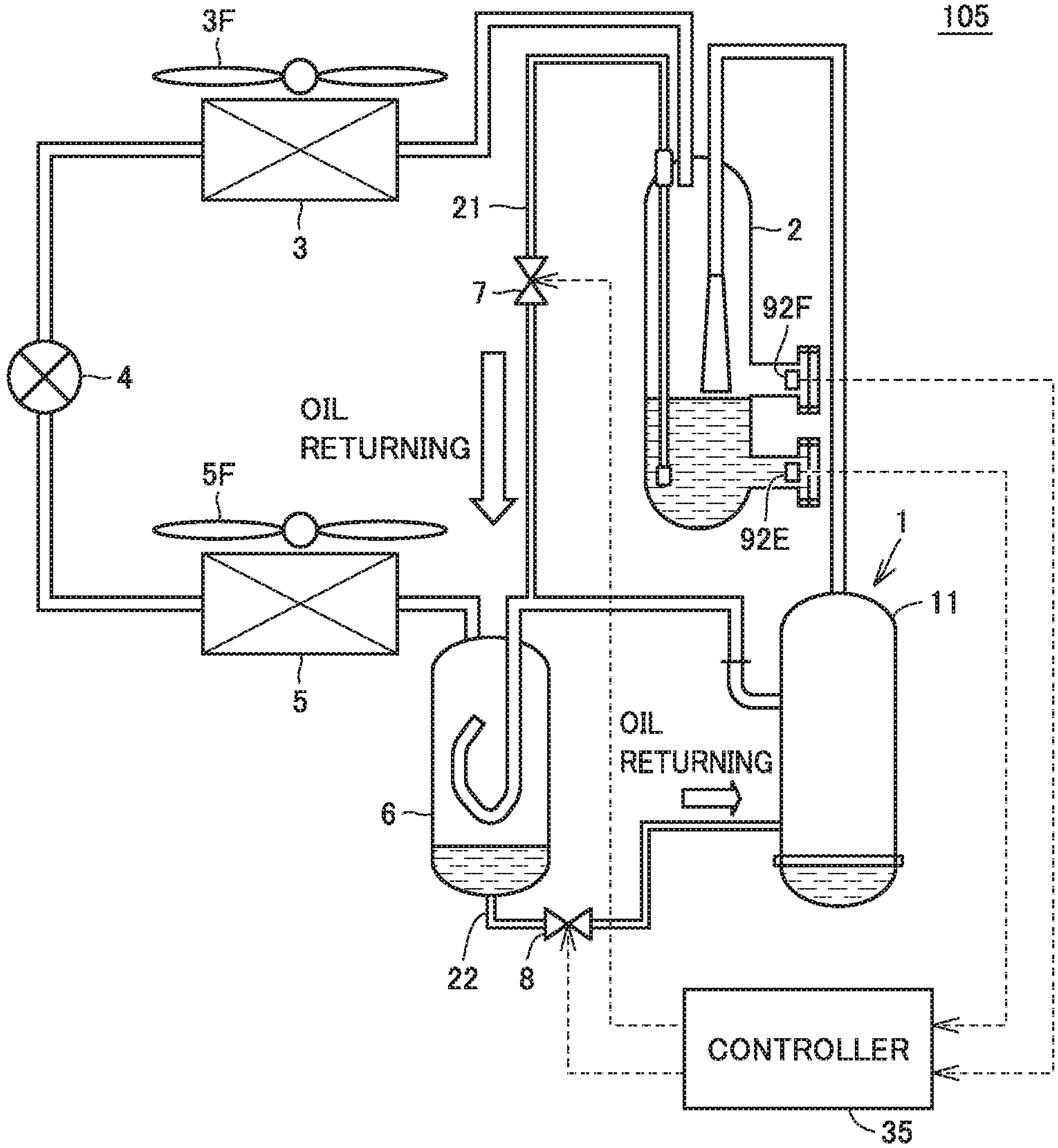

START
SENSOR 91M OUTPUTS GAS VOLTAGE?
S51
NO
YES
S52
OPEN ELECTROMAGNETIC VALVE 8
PREDETERMINED TIME PASSED?
S53
NO
YES
S54
CLOSE ELECTROMAGNETIC VALVE 8
SENSOR 91M OUTPUTS GAS VOLTAGE?
S55
NO
YES
S56
OPEN ELECTROMAGNETIC VALVE 7
PREDETERMINED TIME PASSED?
S57
NO
YES
S58
CLOSE ELECTROMAGNETIC VALVE 7
SENSOR 92F OUTPUTS OIL VOLTAGE?
S59
NO
YES
S60
OPEN ELECTROMAGNETIC VALVE 7
PREDETERMINED TIME PASSED?
S61
NO
YES
S62
CLOSE ELECTROMAGNETIC VALVE 7
RETURN

FIG.13



105
3F
3
21
2
7
92F
4
OIL
RETURNING
5F
92E
1
11
5
OIL
RETURNING
6
22
8
CONTROLLER
35

FIG.14

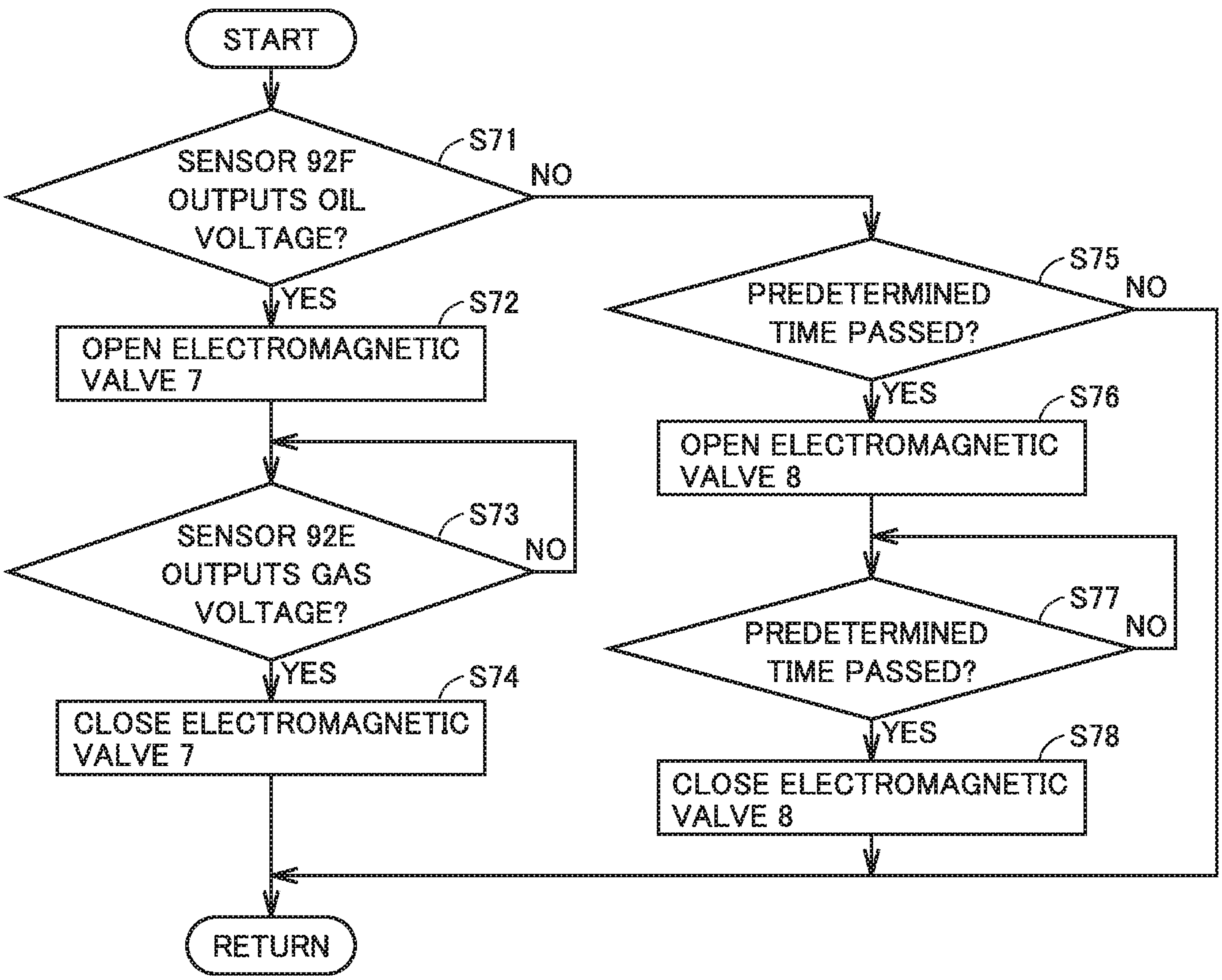

START
SENSOR 92F OUTPUTS OIL VOLTAGE?
S71
NO
YES
S72
OPEN ELECTROMAGNETIC VALVE 7
SENSOR 92E OUTPUTS GAS VOLTAGE?
S73
NO
YES
S74
CLOSE ELECTROMAGNETIC VALVE 7
PREDETERMINED TIME PASSED?
S75
NO
YES
S76
OPEN ELECTROMAGNETIC VALVE 8
PREDETERMINED TIME PASSED?
S77
NO
YES
S78
CLOSE ELECTROMAGNETIC VALVE 8
RETURN

FIG.15

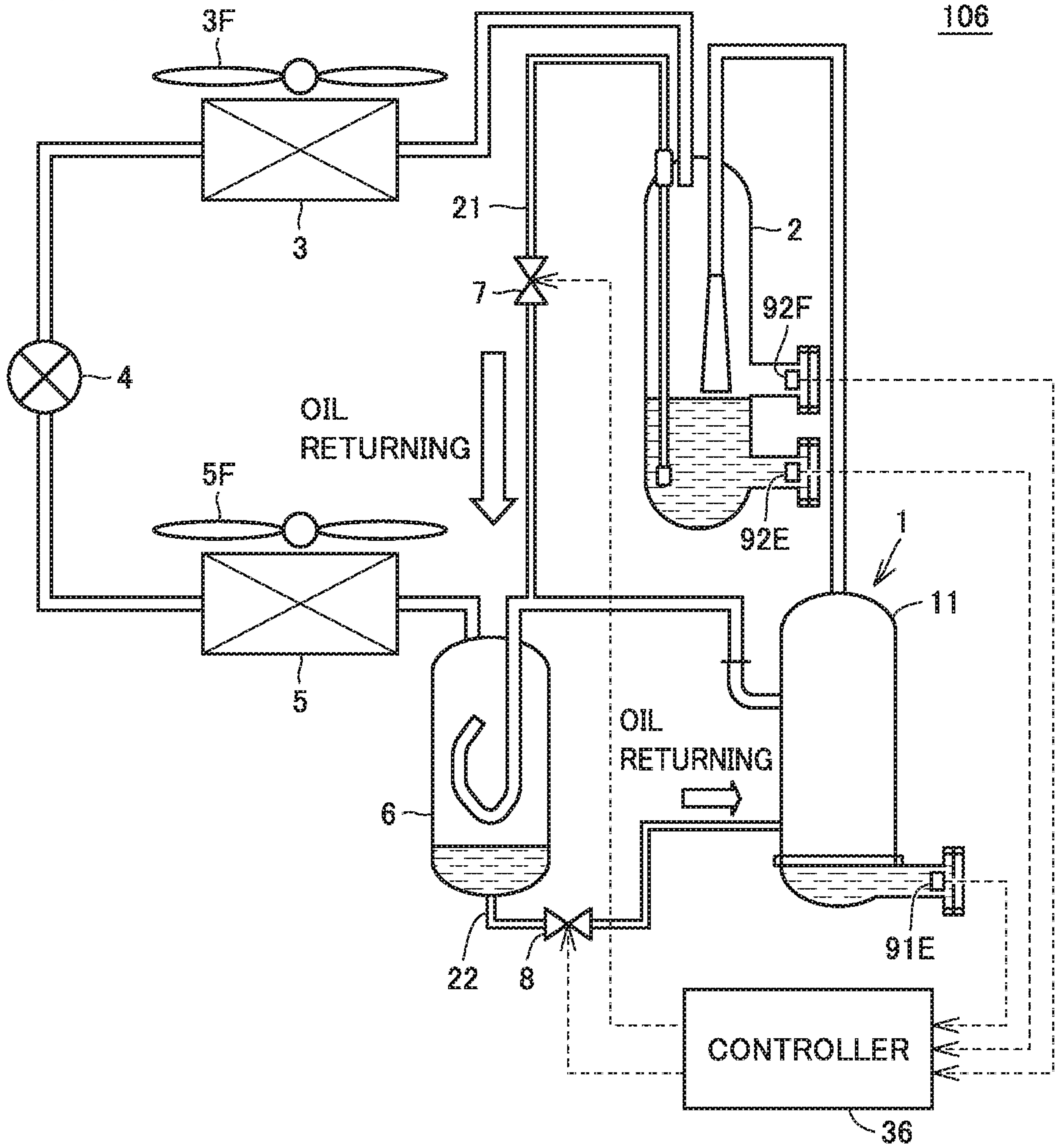

106
3F
3
21
7
2
92F
4
OIL
RETURNING
5F
92E
1
11
5
OIL
RETURNING
6
22
8
91E
CONTROLLER
36

FIG.16

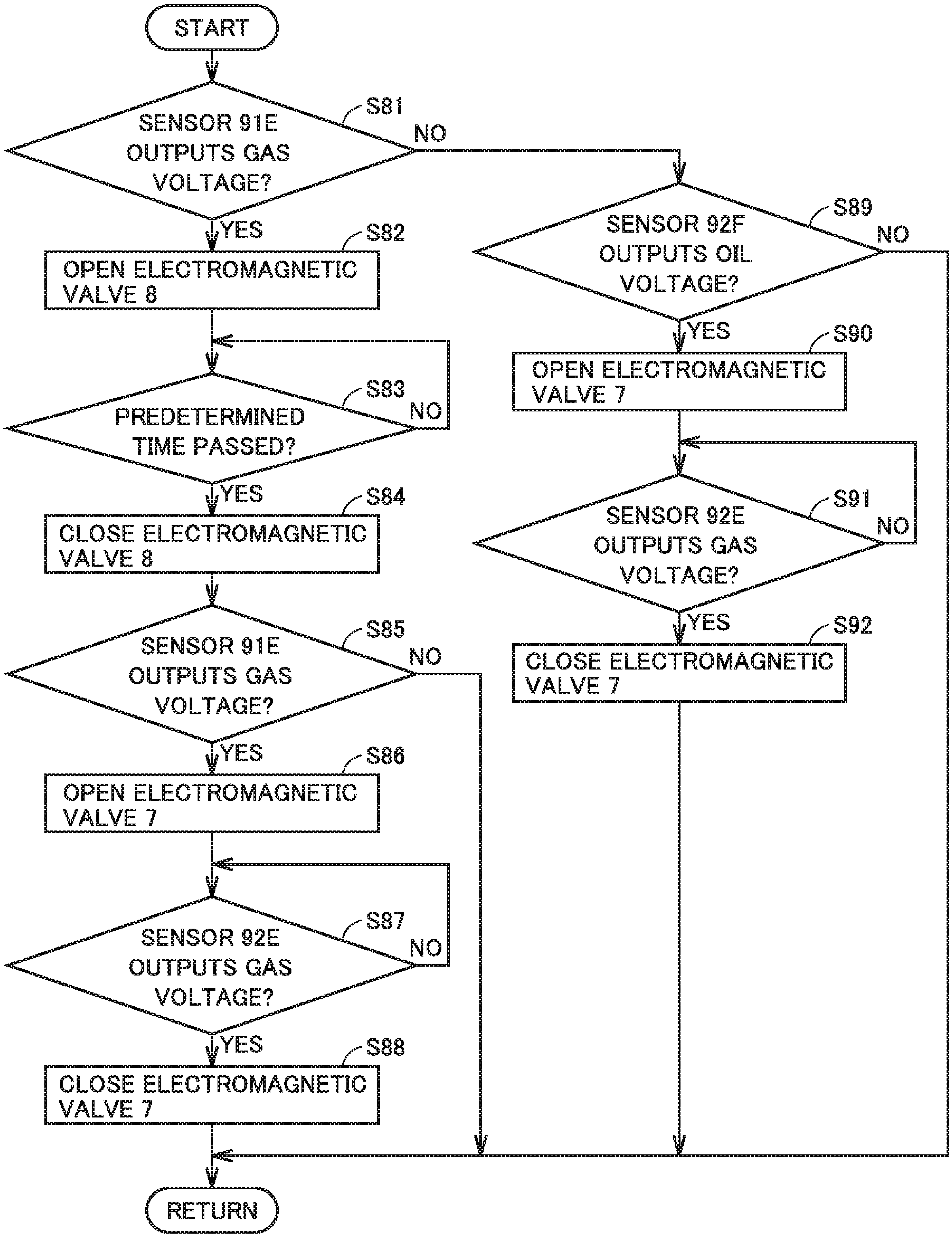

START
SENSOR 91E OUTPUTS GAS VOLTAGE?
S81
NO
YES
S82
OPEN ELECTROMAGNETIC VALVE 8
S83
PREDETERMINED TIME PASSED?
NO
YES
S84
CLOSE ELECTROMAGNETIC VALVE 8
S85
SENSOR 91E OUTPUTS GAS VOLTAGE?
NO
YES
S86
OPEN ELECTROMAGNETIC VALVE 7
S87
SENSOR 92E OUTPUTS GAS VOLTAGE?
NO
YES
S88
CLOSE ELECTROMAGNETIC VALVE 7
S89
SENSOR 92F OUTPUTS OIL VOLTAGE?
NO
YES
S90
OPEN ELECTROMAGNETIC VALVE 7
S91
SENSOR 92E OUTPUTS GAS VOLTAGE?
NO
YES
S92
CLOSE ELECTROMAGNETIC VALVE 7
RETURN

FIG.17

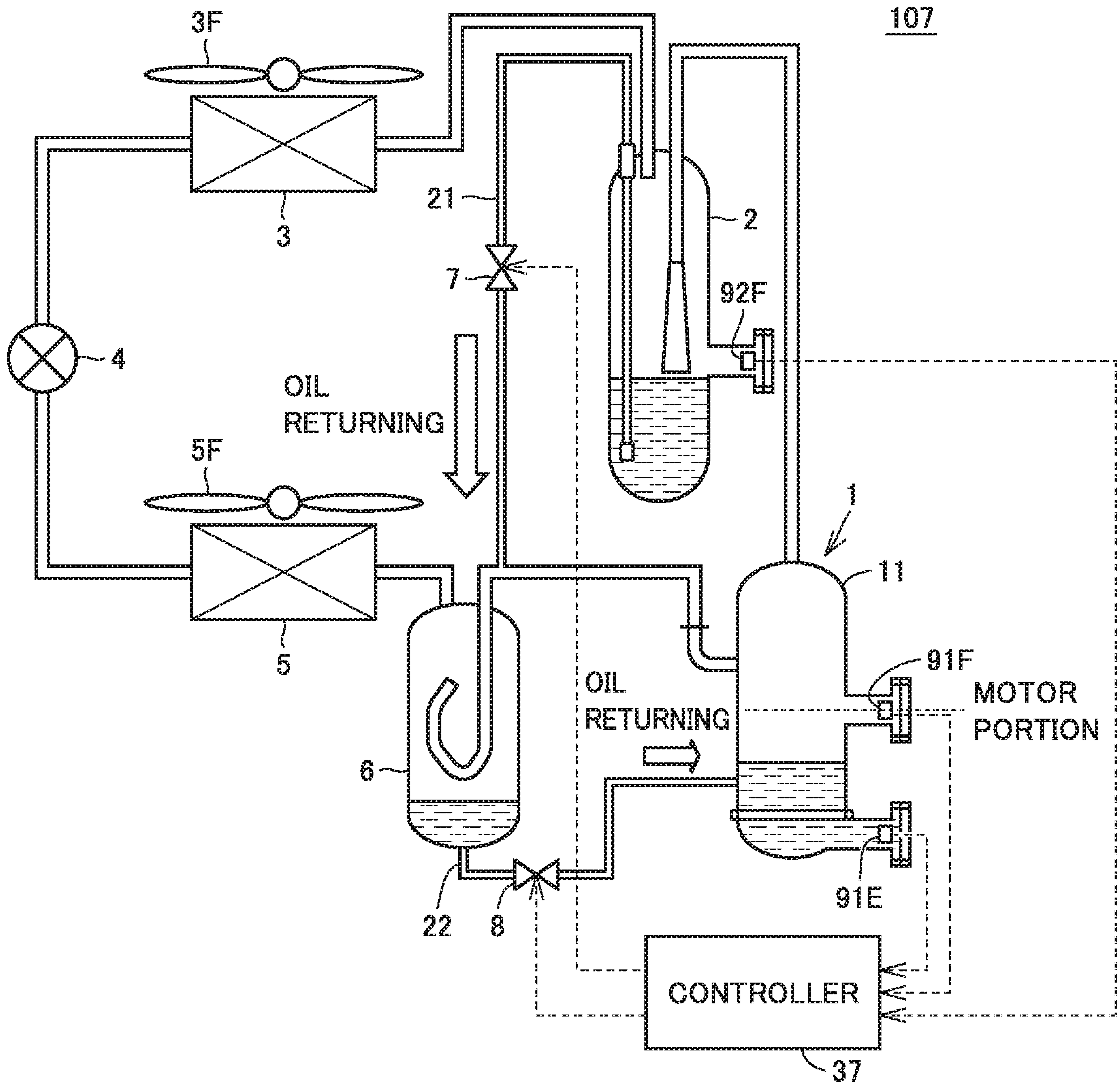

107
3F
3
21
2
7
92F
4
OIL
RETURNING
5F
1
11
5
91F
MOTOR
PORTION
OIL
RETURNING
6
91E
22
8
CONTROLLER
37

FIG.18

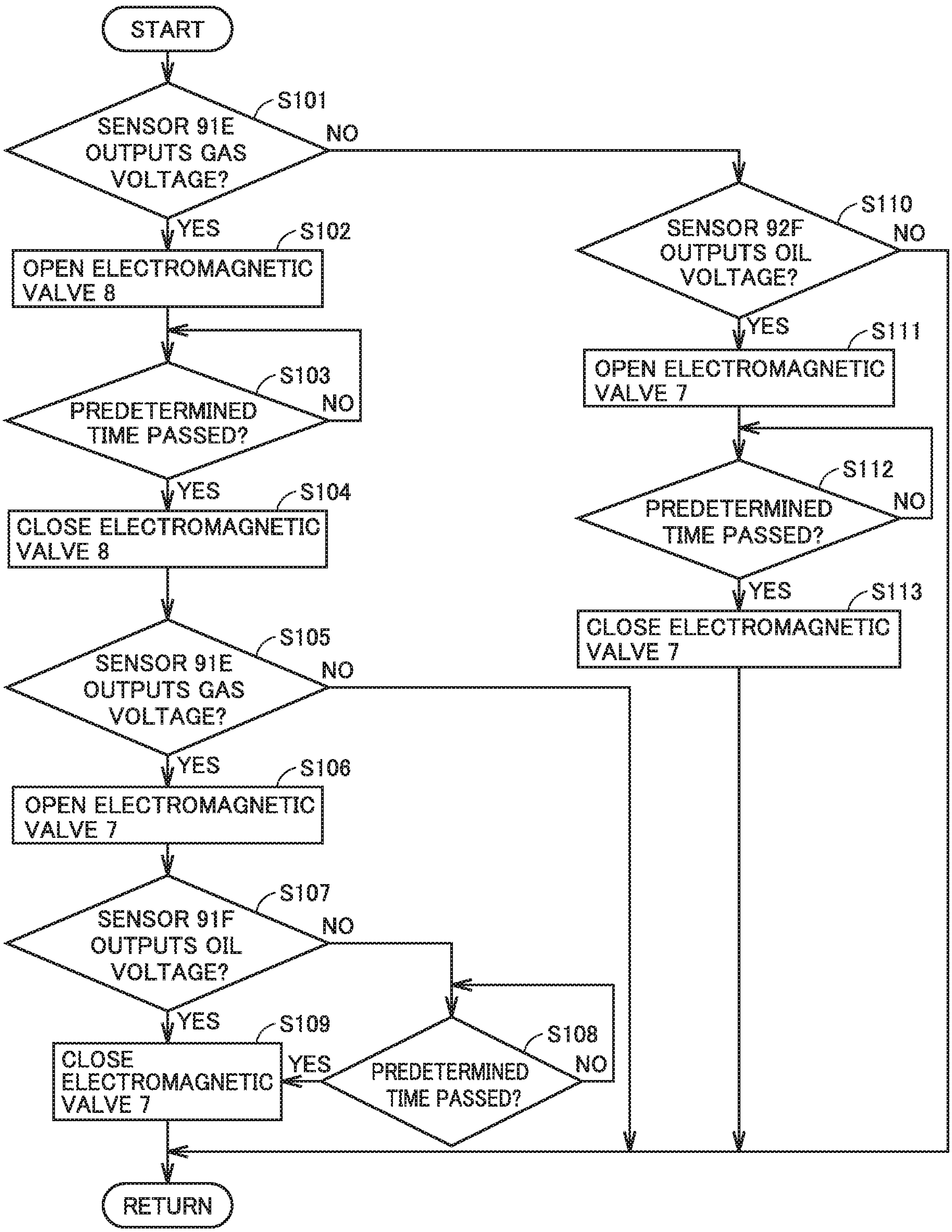

START
SENSOR 91E OUTPUTS GAS VOLTAGE?
S101
NO
YES
OPEN ELECTROMAGNETIC VALVE 8
S102
PREDETERMINED TIME PASSED?
S103
NO
YES
CLOSE ELECTROMAGNETIC VALVE 8
S104
SENSOR 91E OUTPUTS GAS VOLTAGE?
S105
NO
YES
OPEN ELECTROMAGNETIC VALVE 7
S106
SENSOR 91F OUTPUTS OIL VOLTAGE?
S107
NO
YES
CLOSE ELECTROMAGNETIC VALVE 7
S109
YES
PREDETERMINED TIME PASSED?
S108
NO
SENSOR 92F OUTPUTS OIL VOLTAGE?
S110
NO
YES
OPEN ELECTROMAGNETIC VALVE 7
S111
PREDETERMINED TIME PASSED?
S112
NO
YES
CLOSE ELECTROMAGNETIC VALVE 7
S113
RETURN

FIG.19

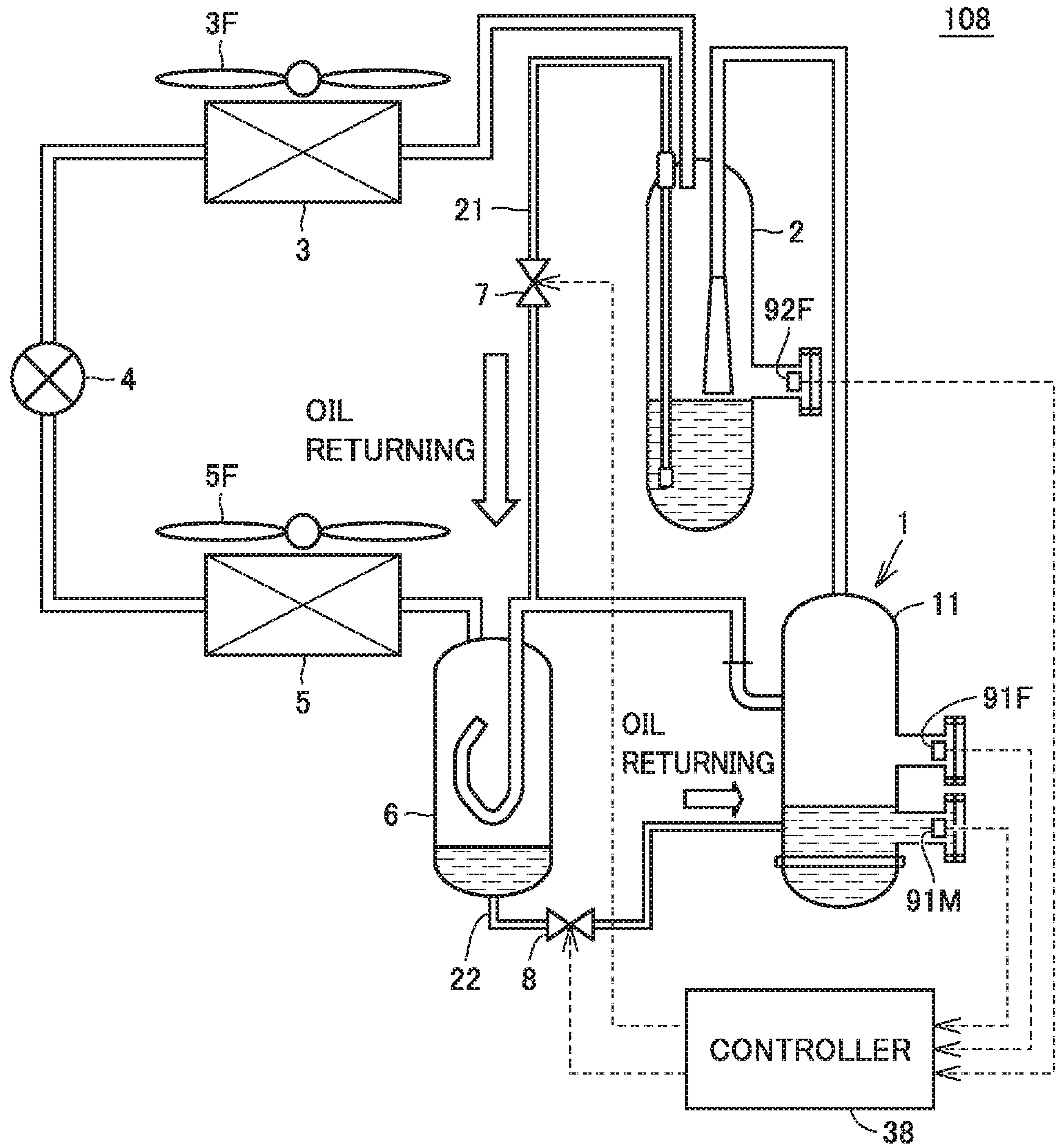

108
3F
3
21
2
7
92F
4
OIL
RETURNING
5F
5
1
11
91F
OIL
RETURNING
6
91M
22
8
CONTROLLER
38

FIG.20

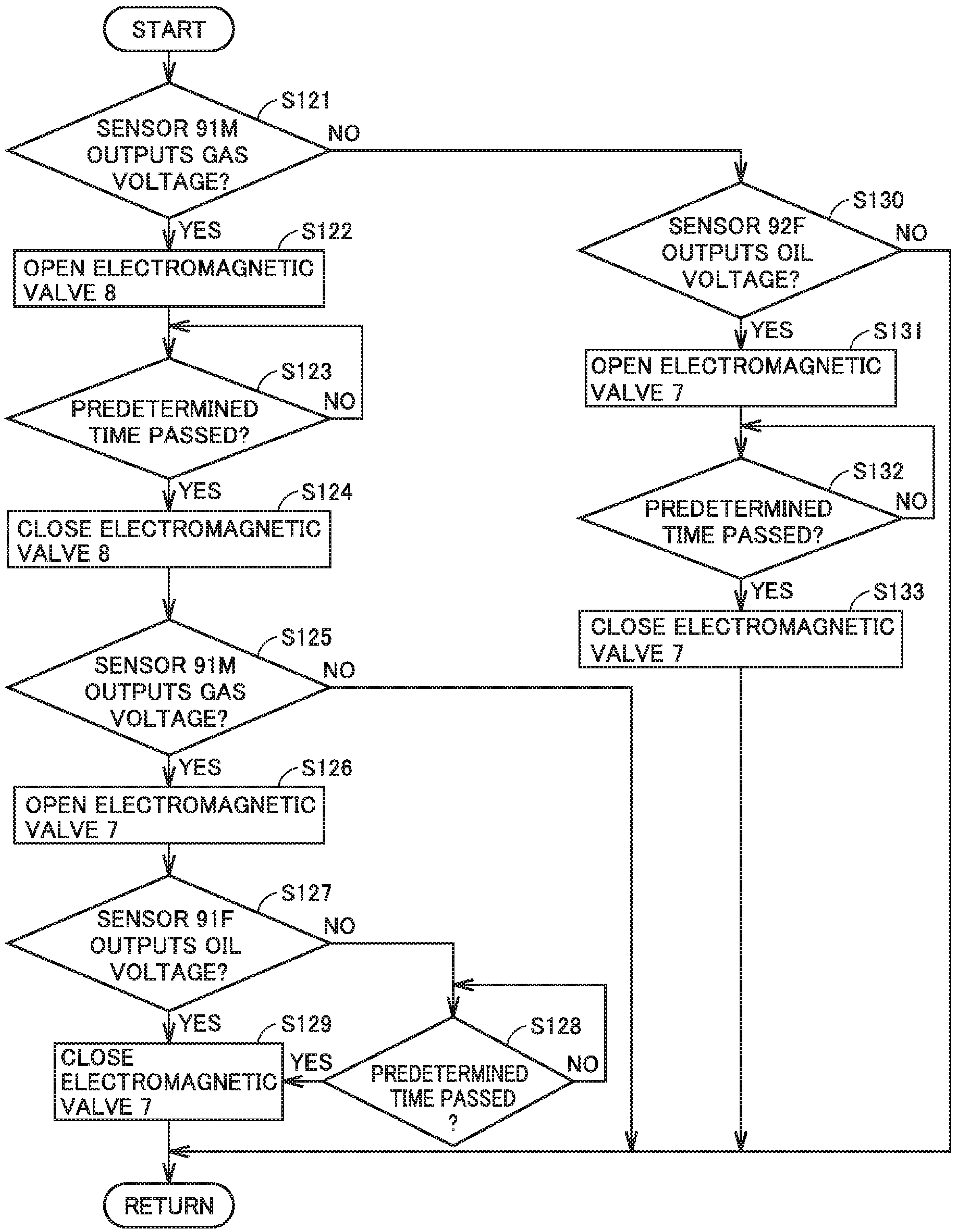

START
S121
SENSOR 91M OUTPUTS GAS VOLTAGE?
NO
YES
S122
OPEN ELECTROMAGNETIC VALVE 8
S123
PREDETERMINED TIME PASSED?
NO
YES
S124
CLOSE ELECTROMAGNETIC VALVE 8
S125
SENSOR 91M OUTPUTS GAS VOLTAGE?
NO
YES
S126
OPEN ELECTROMAGNETIC VALVE 7
S127
SENSOR 91F OUTPUTS OIL VOLTAGE?
NO
YES
S129
CLOSE ELECTROMAGNETIC VALVE 7
YES
S128
PREDETERMINED TIME PASSED ?
NO
S130
SENSOR 92F OUTPUTS OIL VOLTAGE?
NO
YES
S131
OPEN ELECTROMAGNETIC VALVE 7
S132
PREDETERMINED TIME PASSED?
NO
YES
S133
CLOSE ELECTROMAGNETIC VALVE 7
RETURN

FIG.21

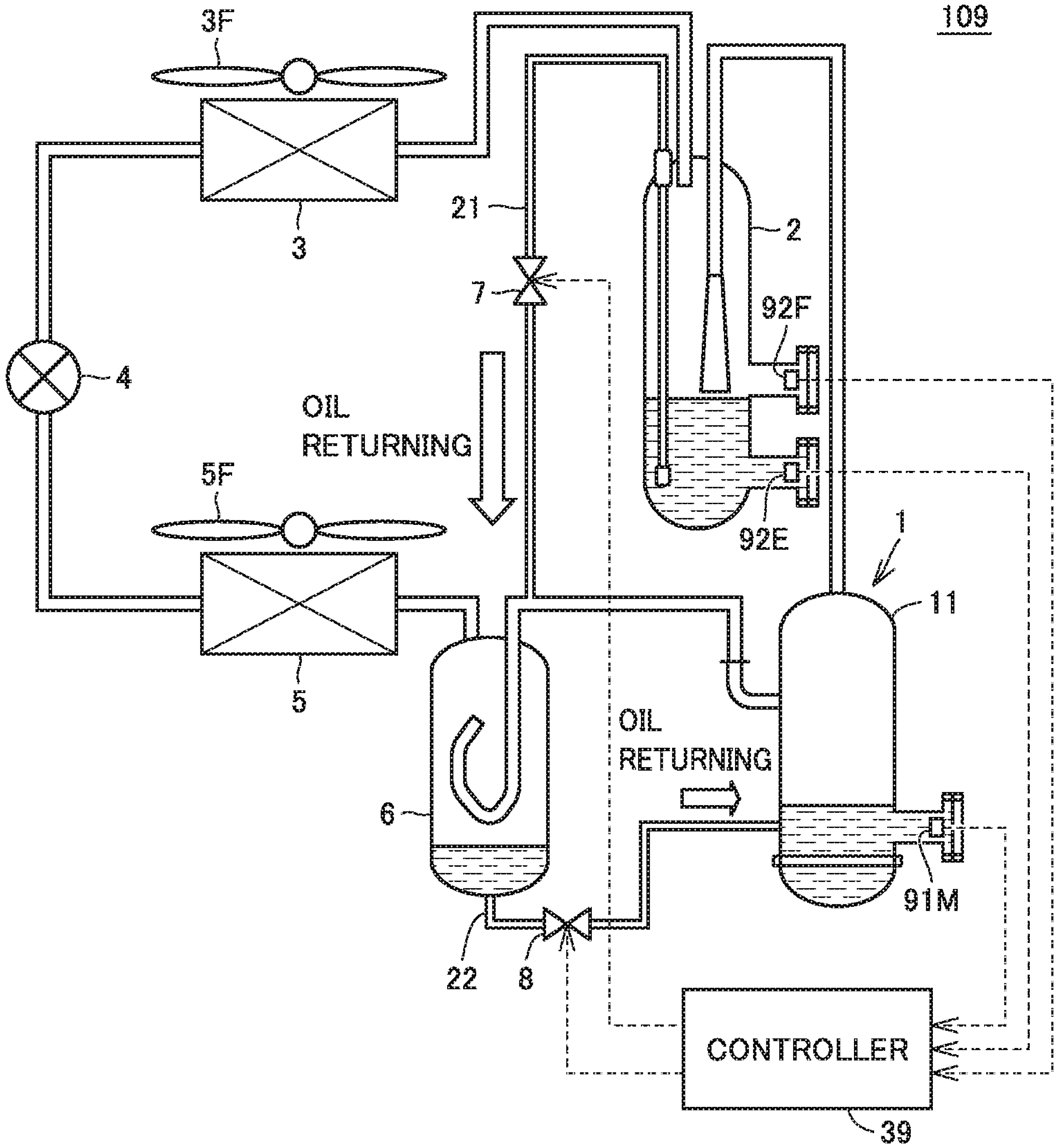

3F
109
21
2
3
7
92F
4
OIL
RETURNING
5F
92E
1
11
5
OIL
RETURNING
6
91M
22
8
CONTROLLER
39

FIG.22

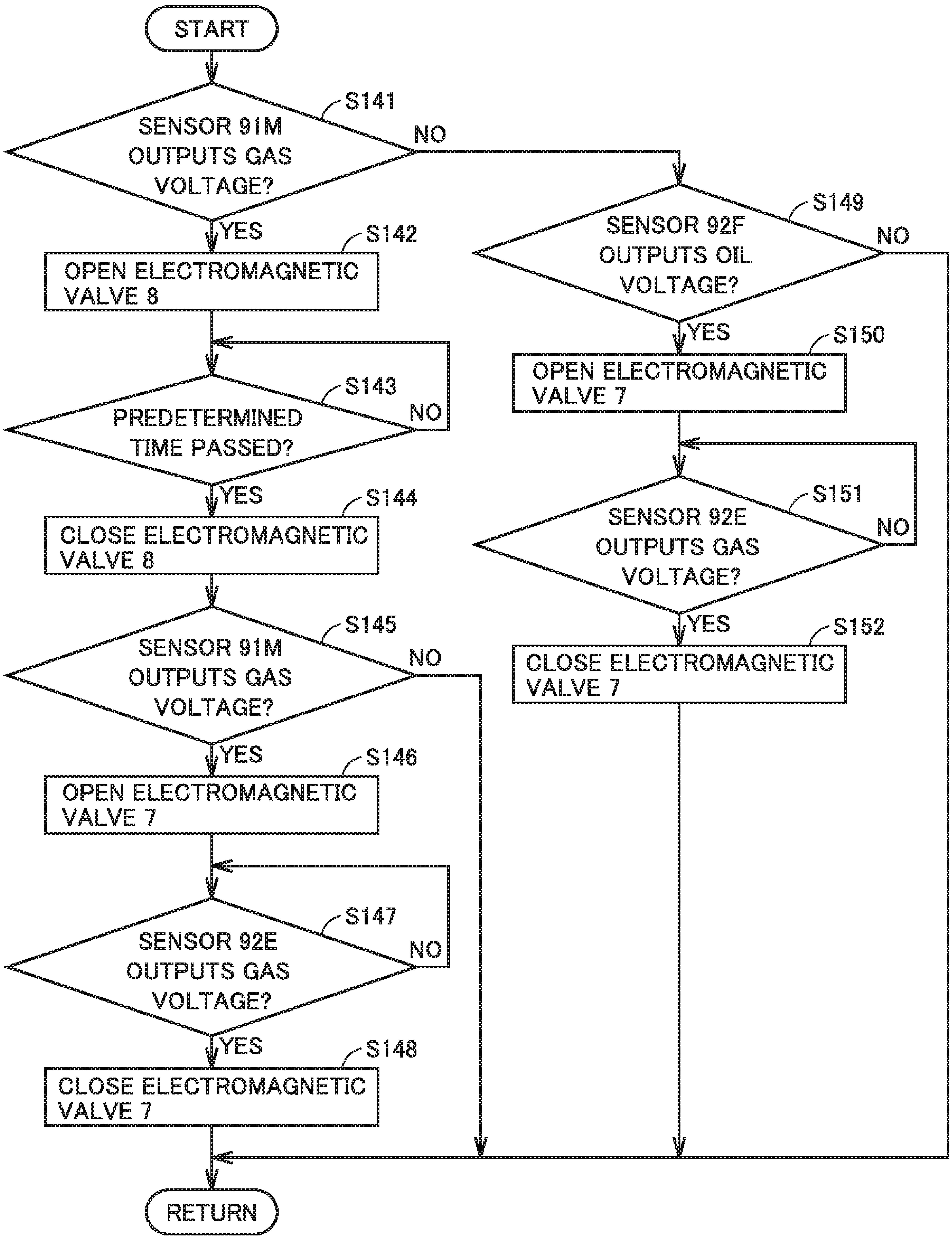
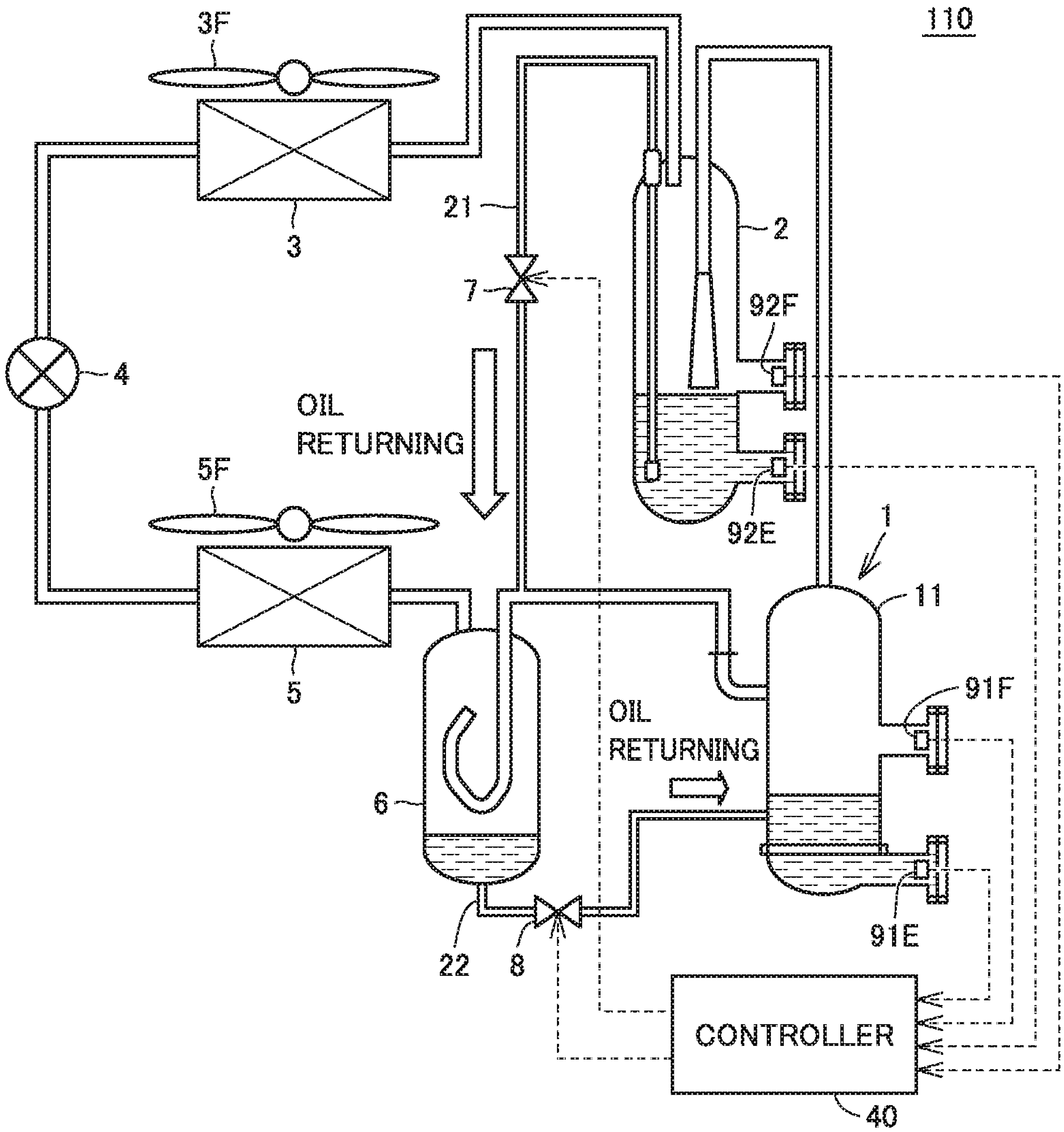

START
S141
SENSOR 91M OUTPUTS GAS VOLTAGE?
NO
YES
S142
OPEN ELECTROMAGNETIC VALVE 8
S143
PREDETERMINED TIME PASSED?
NO
YES
S144
CLOSE ELECTROMAGNETIC VALVE 8
S145
SENSOR 91M OUTPUTS GAS VOLTAGE?
NO
YES
S146
OPEN ELECTROMAGNETIC VALVE 7
S147
SENSOR 92E OUTPUTS GAS VOLTAGE?
NO
YES
S148
CLOSE ELECTROMAGNETIC VALVE 7
S149
SENSOR 92F OUTPUTS OIL VOLTAGE?
NO
YES
S150
OPEN ELECTROMAGNETIC VALVE 7
S151
SENSOR 92E OUTPUTS GAS VOLTAGE?
NO
YES
S152
CLOSE ELECTROMAGNETIC VALVE 7
RETURN

FIG.23



110
3F
3
21
2
7
92F
4
OIL
RETURNING
5F
92E
1
11
5
91F
OIL
RETURNING
6
91E
22
8
CONTROLLER
40

FIG.24

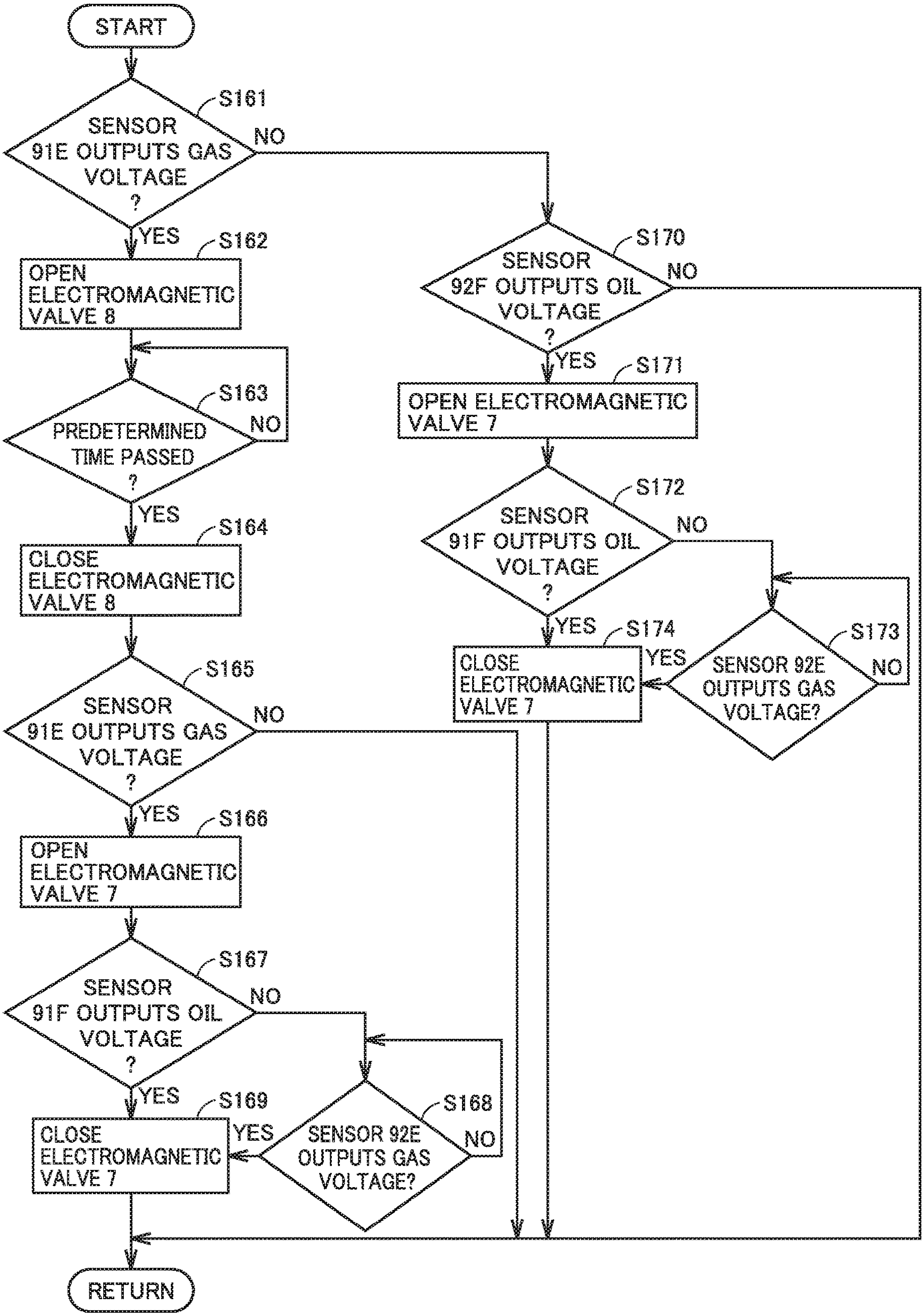

START
S161
SENSOR 91E OUTPUTS GAS VOLTAGE ?
NO
YES
S162
OPEN ELECTROMAGNETIC VALVE 8
S163
PREDETERMINED TIME PASSED ?
NO
YES
S164
CLOSE ELECTROMAGNETIC VALVE 8
S165
SENSOR 91E OUTPUTS GAS VOLTAGE ?
NO
YES
S166
OPEN ELECTROMAGNETIC VALVE 7
S167
SENSOR 91F OUTPUTS OIL VOLTAGE ?
NO
YES
S168
SENSOR 92E OUTPUTS GAS VOLTAGE?
NO
YES
S169
CLOSE ELECTROMAGNETIC VALVE 7
S170
SENSOR 92F OUTPUTS OIL VOLTAGE ?
NO
YES
S171
OPEN ELECTROMAGNETIC VALVE 7
S172
SENSOR 91F OUTPUTS OIL VOLTAGE ?
NO
YES
S173
SENSOR 92E OUTPUTS GAS VOLTAGE?
NO
YES
S174
CLOSE ELECTROMAGNETIC VALVE 7
RETURN

FIG.25

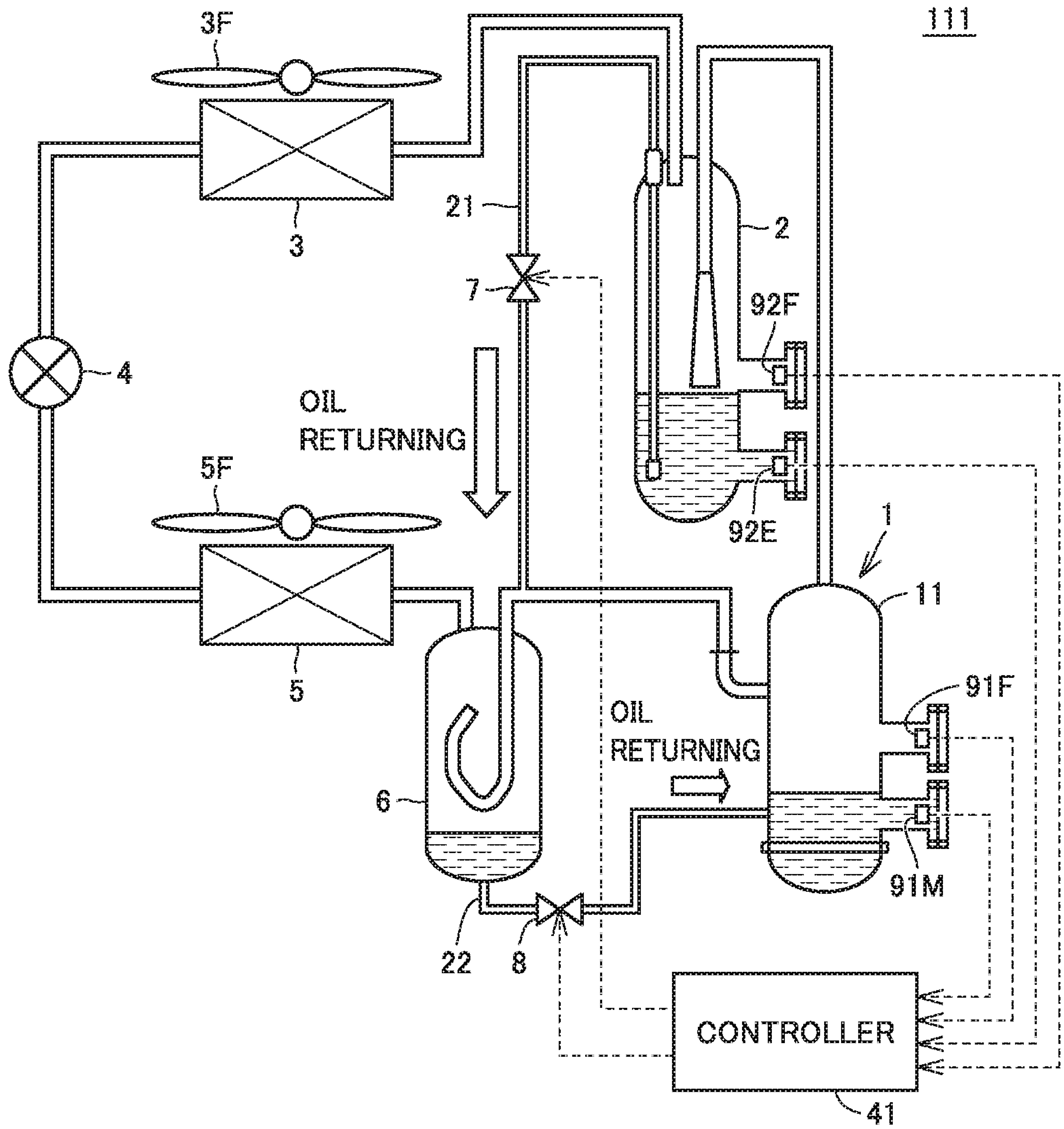
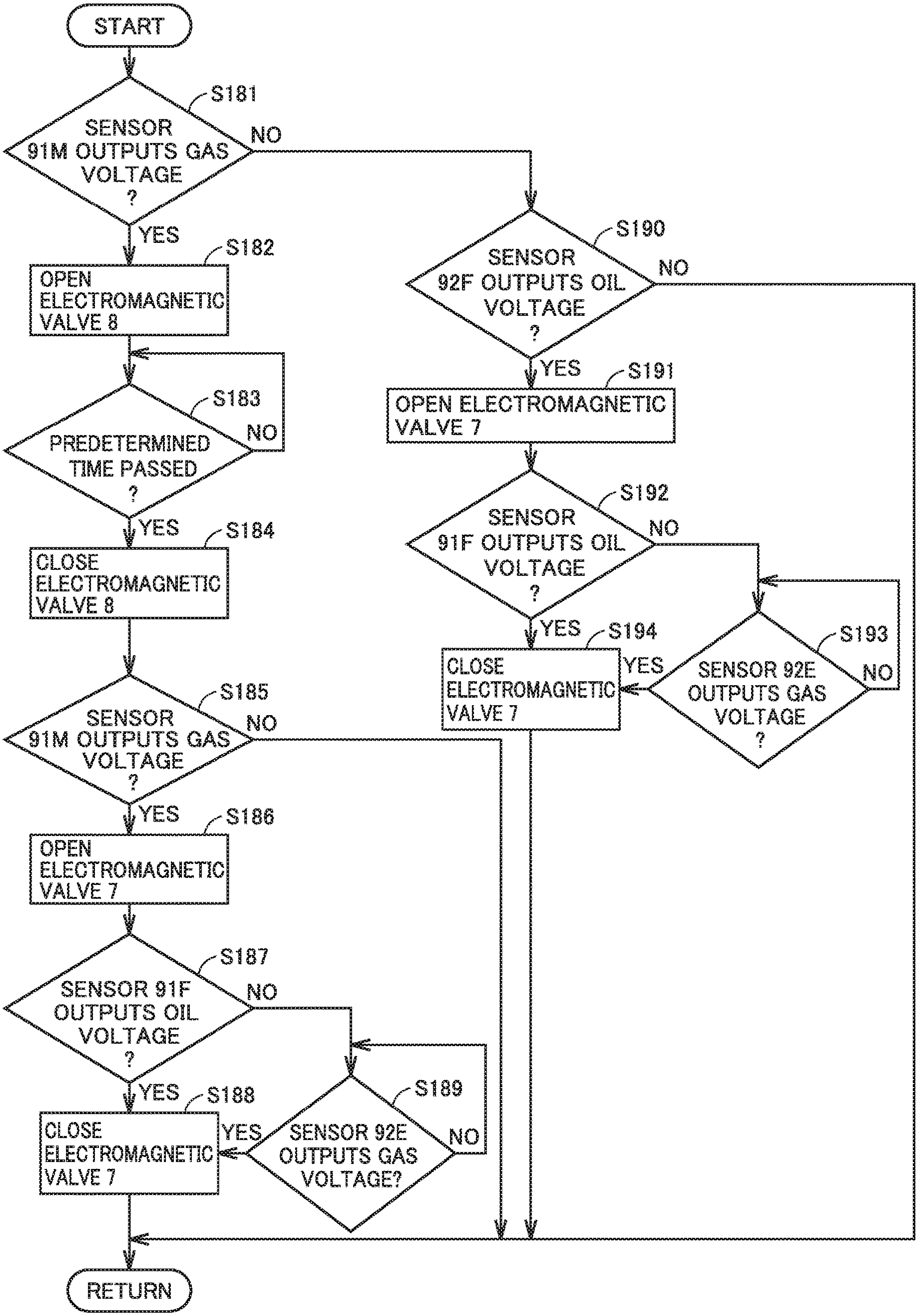

111
3F
3
4
5F
5
21
7
OIL
RETURNING
2
92F
92E
1
11
91F
OIL
RETURNING
91M
6
22
8
CONTROLLER
41

FIG.26


START
S181
SENSOR 91M OUTPUTS GAS VOLTAGE ?
NO
YES
S182
OPEN ELECTROMAGNETIC VALVE 8
S183
PREDETERMINED TIME PASSED ?
NO
YES
S184
CLOSE ELECTROMAGNETIC VALVE 8
S185
SENSOR 91M OUTPUTS GAS VOLTAGE ?
NO
YES
S186
OPEN ELECTROMAGNETIC VALVE 7
S187
SENSOR 91F OUTPUTS OIL VOLTAGE ?
NO
YES
S188
CLOSE ELECTROMAGNETIC VALVE 7
S189
SENSOR 92E OUTPUTS GAS VOLTAGE?
YES
NO
S190
SENSOR 92F OUTPUTS OIL VOLTAGE ?
NO
YES
S191
OPEN ELECTROMAGNETIC VALVE 7
S192
SENSOR 91F OUTPUTS OIL VOLTAGE ?
NO
YES
S194
CLOSE ELECTROMAGNETIC VALVE 7
S193
SENSOR 92E OUTPUTS GAS VOLTAGE ?
YES
NO
RETURN

REFRIGERATION CYCLE APPARATUS

CROSS REFERENCE TO RELATED APPLICATION

This application is a U.S. national stage application PCT/JP2016/082348 filed on Oct. 31, 2016, the contents of which are incorporated herein by reference.

TECHNICAL FIELD

The present invention relates to a refrigeration cycle apparatus having an oil returning path.

BACKGROUND ART

Conventionally, in an refrigeration cycle apparatus including a compressor, a condenser, an expansion valve, and an evaporator, an oil separator is provided at the discharge side of the compressor because refrigeration oil is discharged from the compressor together with refrigerant. In order to prevent oil shortage in the compressor, an oil returning path is provided to return, to the suction side of the compressor, the refrigeration oil separated from the refrigerant in the oil separator. By opening and closing an on-off valve on the oil returning path, an amount of oil in the compressor is adjusted (for example, see Japanese Utility Model Laying-Open No. 3-73880 (Patent Literature 1)).

CITATION LIST

Patent Literature

PTL 1: Japanese Utility Model Laying-Open No. 3-73880

SUMMARY OF INVENTION

Technical Problem

In the refrigerant circuit described in Japanese Utility Model Laying-Open No. 3-73880, the opening and closing of the on-off valve on the oil returning path are controlled based on time. However, in this method, since a precise amount of oil cannot be checked, the on-off valve is open even after completion of the returning of the refrigeration oil into a container, with the result that not only the refrigeration oil but also the refrigerant are returned to the compressor. Accordingly, it is expected that refrigerator performance is decreased due to a decreased flow rate of the refrigerant to the evaporator and that controllability of an internal temperature of the refrigerator is deteriorated due to a frequency change of the compressor. Moreover, when an excess of oil is returned, a motor of the compressor is soaked in the oil, thus resulting in such a concern that the volume efficiency of the compressor is decreased.

The present invention has been made to solve the above-described problem, and has an object to not only protect a compressor but also prevent decreased performances of the compressor and a refrigeration cycle apparatus by accurately detecting an oil level using a sensor so as to precisely return oil to a container of the compressor.

Solution to Problem

A refrigeration cycle apparatus according to a main aspect is a refrigeration cycle apparatus in which refrigerant circulates in an order of a compressor, a first oil separator, a

condenser, an expansion valve, an evaporator, and a second oil separator. The refrigeration cycle apparatus includes: a first bypass path extending from the first oil separator to the compressor; a first on-off valve provided on the first bypass path; a second bypass path extending from the second oil separator to the compressor; a second on-off valve provided on the second bypass path; and a controller configured to control a degree of opening of the first on-off valve and a degree of opening of the second on-off valve.

Advantageous Effects of Invention

Reliability of the refrigeration cycle apparatus according to the present invention for preventing oil shortage in the compressor can be improved by controlling the degrees of opening of the first on-off valve and the second on-off valve by the controller so as to precisely adjust an amount of returning of the oil.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is an entire configuration diagram of a refrigeration cycle apparatus according to a first embodiment.

FIG. **2** shows a configuration of a self-heating sensor.

FIG. **3** shows characteristics of the self-heating sensor.

FIG. **4** is a flowchart for illustrating oil returning control in the first embodiment.

FIG. **5** is an entire configuration diagram of a refrigeration cycle apparatus according to a second embodiment.

FIG. **6** is a flowchart for illustrating oil returning control in the second embodiment.

FIG. **7** is an entire configuration diagram of a refrigeration cycle apparatus according to a third embodiment.

FIG. **8** is a flowchart for illustrating oil returning control in the third embodiment.

FIG. **9** is an entire configuration diagram of a refrigeration cycle apparatus according to a fourth embodiment.

FIG. **10** is a flowchart for illustrating oil returning control in the fourth embodiment.

FIG. **11** is an entire configuration diagram of a refrigeration cycle apparatus according to a fifth embodiment.

FIG. **12** is a flowchart for illustrating oil returning control in the fifth embodiment.

FIG. **13** is an entire configuration diagram of a refrigeration cycle apparatus according to a sixth embodiment.

FIG. **14** is a flowchart for illustrating oil returning control in the sixth embodiment.

FIG. **15** is an entire configuration diagram of a refrigeration cycle apparatus according to a seventh embodiment.

FIG. **16** is a flowchart for illustrating oil returning control in the seventh embodiment.

FIG. **17** is an entire configuration diagram of a refrigeration cycle apparatus according to an eighth embodiment.

FIG. **18** is a flowchart for illustrating oil returning control in the eighth embodiment.

FIG. **19** is an entire configuration diagram of a refrigeration cycle apparatus according to a ninth embodiment.

FIG. **20** is a flowchart for illustrating oil returning control in the ninth embodiment.

FIG. **21** is an entire configuration diagram of a refrigeration cycle apparatus according to a tenth embodiment.

FIG. **22** is a flowchart for illustrating oil returning control in the tenth embodiment.

FIG. **23** is an entire configuration diagram of a refrigeration cycle apparatus according to an eleventh embodiment.

FIG. **24** is a flowchart for illustrating oil returning control in the eleventh embodiment.

FIG. **25** is an entire configuration diagram of a refrigeration cycle apparatus according to a twelfth embodiment.

FIG. **26** is a flowchart for illustrating oil returning control in the twelfth embodiment.

DESCRIPTION OF EMBODIMENTS

The following describes an embodiment of the present invention in detail with reference to figures. In the description below, a plurality of embodiments will be described; however, it is initially expected at the time of filing of the present application to appropriately combine configurations described in the embodiments. It should be noted that the same or corresponding portions are given the same reference characters and are not described repeatedly.

First Embodiment

FIG. **1** is an entire configuration diagram of a refrigeration cycle apparatus according to a first embodiment. With reference to FIG. **1**, refrigeration cycle apparatus **100** includes a compressor **1**, an oil separator **2**, a condenser **3**, an expansion valve **4**, an evaporator **5**, an accumulator **6**, and a controller **30**.

Compressor **1**, oil separator **2**, condenser **3**, expansion valve **4**, evaporator **5**, and accumulator **6** are connected in this order, thus forming a refrigerant circuit. Each of oil separator **2** and accumulator **6** also operates as an "oil separator". In addition to the refrigerant circuit, refrigeration cycle apparatus **100** is provided with oil returning paths **21**, **22** for returning refrigeration oil to compressor **1**. Although not shown in the figure, each of oil returning paths **21**, **22** includes a capillary tube for reducing a flow rate. Electromagnetic valves **7**, **8** are disposed on oil returning paths **21**, **22**, respectively. It should be noted that each of electromagnetic valves **7**, **8** does not need to be an electromagnetic valve as long as a degree of opening thereof can be changed, and may be an on-off valve that can include an electronically controlled valve, an electrically operated valve, or the like. Oil separator **2** and accumulator **6** are connected to compressor **1** via oil returning paths **21**, **22**. Electromagnetic valves **7**, **8** are disposed on oil returning paths **21**, **22**. A self-heating sensor **91**E configured to detect an amount of lubricating oil is attached to a low shell portion of compressor **1** corresponding to a limit of height with which reliability can be secured from oil shortage. The low shell portion can be, for example, substantially as high as an oil suction hole of an oil pump in such a configuration that the refrigeration oil is suctioned using the oil pump and is supplied to a motor in the compressor or a sliding portion of a scroll compressor. Moreover, compressor **1** has a shape obtained by combining curved upper arm portion and lower arm portion with a straight shell portion that connects the upper arm portion to the lower arm portion. The low shell portion may correspond to the lower arm portion.

The following first describes an operation of refrigeration cycle apparatus **100**. The refrigerant is compressed by compressor **1** and becomes a high-temperature and high-pressure overheated gas. In condenser **3**, heat exchange is performed between the refrigerant and external air, and the refrigerant becomes a high-pressure saturated liquid. The refrigerant is decompressed when passing through expansion valve **4**. Internal air of the refrigerator is supplied to evaporator **5** by an evaporator fan **5**F to exchange heat with the refrigerant, with the result that the refrigerant becomes a low-pressure saturated gas or overheated gas. Then, in accumulator **6**, the liquid refrigerant is separated from the gas refrigerant, and the gas refrigerant is supplied to compressor **1**.

Compressor **1** includes a casing **11**, a motor, and a scroll compressor. In casing **11**, motor and scroll compressor driven to rotate by motor are accommodated. The refrigerant is compressed by scroll compressor and is discharged from compressor **1**. Compressor **1** may include a rotary compressor instead of scroll compressor.

Next, the following describes flows of the refrigerant and the refrigeration oil. The discharged mixture of the high-temperature and high-pressure refrigerant and the refrigeration oil from compressor **1** flows into oil separator **2**, and the refrigerant and the refrigeration oil are roughly separated due to actions of centrifugal separation, gravity, filter, and the like. Since the refrigeration oil is separated by oil separator **2**, it is possible to suppress decrease in heat transfer performance due to mixing of the refrigeration oil, and suppress decrease in cycle performance due to increase in pressure loss. Moreover, when self-heating sensor **91**E disposed in compressor **1** detects insufficiency of the refrigeration oil, the refrigeration oil separated by oil separator **2** is supplied to compressor **1** by opening electromagnetic valve **7** on oil returning path **21**. It should be noted that the refrigeration oil that could not have been separated from the refrigerant in oil separator **2** is returned to compressor **1** via condenser **3**, expansion valve **4**, evaporator **5**, and accumulator **6**. On this occasion, in order to prevent a liquid-back phenomenon, the refrigeration oil is also separated, together with the liquid refrigerant, from the gas refrigerant by accumulator **6**.

Next, the following describes a situation in which the amount of oil in the compressor is decreased. When the mixture of the refrigerant and the refrigeration oil is returned to compressor **1** via condenser **3**, expansion valve **4**, and evaporator **5**, the moving speed of the refrigeration oil is slower than the moving speed of the refrigerant, with the result that the refrigeration oil exists to be accumulated in a pipe and the like. When components of one refrigerant circuit are connected by a long pipe, such accumulation is noticeable.

In consideration of such a situation, an amount of oil introduced in refrigeration cycle apparatus **100** has to be large. However, if the refrigeration oil in the refrigerant can be separated by oil separator **2**, a circulation ratio of the refrigeration oil to the refrigerant becomes low, whereby the length of the connecting pipe does not much affect decrease in the amount of oil in compressor **1** (=increase in the amount of introduced oil).

Conversely, it is said that a case where a capability of separating the refrigeration oil in oil separator **2** is exceeded corresponds to the situation in which the amount of oil in compressor **1** is decreased. Particularly, the case corresponds to a situation in which the liquid refrigerant and the refrigeration oil exist in compressor **1**, the liquid refrigerant is abruptly foamed (evaporated), and refrigerant solubility of the refrigeration oil is abruptly decreased. In this case, a large amount of the refrigeration oil in the compressor shell is released from compressor **1** together with the refrigerant. Accordingly, they cannot be separated by oil separator **2** and are returned to compressor **1** via condenser **3**, expansion valve **4**, and evaporator **5**. When the amount of decrease in the amount of the oil in compressor **1** is large by the time at which the large amount of the discharged refrigeration oil is returned, reliability is decreased such as insufficient lubrication of compressor **1**.

(Explanation of Sensor)

In the present embodiment, self-heating sensor **91**E is disposed at the low shell portion of the compressor in order to accurately ascertain the amount of decrease in the amount of the oil in compressor **1**. The following describes a method for detecting an oil level using this self-heating sensor **91**E. FIG. **2** shows a configuration of the self-heating sensor. Self-heating sensor **91**E is a sensor configured to distinguish between gas and liquid by measuring a response when the sensor is supplied with electric power to generate heat. Self-heating sensor **91**E is constituted of two electrodes **23**, **24** and an element **25** having an electric resistance that changes depending on a temperature. Element **25** is disposed between two electrodes **23**, **24**. A fluid state (gas/liquid) at any position inside the oil separator can be determined in accordance with an environmental temperature Tatm measured by a temperature sensor (not shown) and an electrical signal obtained by supplying electric power to self-heating sensor **91**E.

FIG. **3** shows characteristics of the self-heating sensor. Self-heating sensor **91**E generates heat when supplied with electric power. On this occasion, an amount of released heat is changed depending on (i) a difference in heat transfer rate determined by a state (gas/liquid) of the fluid in contact with the sensor and (ii) a difference in environmental temperature Tatm. Accordingly, the temperature of self-heating sensor **91**E is also changed, thus resulting in a difference in sensor voltage depending on the state (gas/liquid) of the fluid.

At each environmental temperature, there is a voltage difference ΔVs between (i) voltage Vso (hereinafter, referred to as "oil voltage") when the sensor is soaked in the refrigeration oil and (ii) voltage Vsg (hereinafter, referred to as "gas voltage") when the sensor is in the gas. By measuring the sensor temperature as a voltage value, whether the fluid in contact therewith is gas or liquid (oil) can be detected. A threshold value range for gas voltage Vsg is determined based on sensor voltage difference ΔVs at each temperature. When the voltage is increased by more than or equal to the threshold value range in such a state that gas voltage Vsg has been detected during monitoring of a change of the sensor voltage with passage of time, it can be determined that the oil is detected. Similarly, based on sensor voltage difference ΔVs at each temperature, a threshold value range for oil voltage Vso is determined. When the voltage is decreased by more than or equal to the threshold value range in such a state that oil voltage Vso has been detected during monitoring of a change of the sensor voltage with passage of time, it can be determined that the gas is detected. It should be noted that a self-heating sensor used in each of below-described second to twelfth embodiments also has such characteristics as shown in FIG. **3**.

(Explanation of Oil Returning Control)

Next, the following describes oil returning control. FIG. **4** is a flowchart for illustrating the oil returning control in the first embodiment. With reference to FIG. **1** and FIG. **4**, controller **30** obtains a voltage value from self-heating sensor **91**E in compressor **1**. In a step S**1**, controller **30** determines whether or not the obtained voltage value indicates gas voltage Vsg. When the voltage value obtained in step S**1** indicates gas voltage Vsg, compressor **1** is in an oil shortage state. Therefore, controller **30** proceeds the process to a step S**2** to open electromagnetic valve **8** on the oil returning path. When electromagnetic valve **8** is opened, the refrigeration oil is returned from accumulator **6** to compressor **1**. After waiting for passage of a predetermined time in a step S**3**, controller **30** proceeds the process to a step S**4** to close electromagnetic valve **8**. Then, in a step S**5**, controller **30** obtains a voltage value from self-heating sensor **91**E in compressor **1**, and determines whether or not the obtained voltage value indicates gas voltage Vsg of FIG. **3**.

When the output of sensor **91**E indicates gas voltage Vsg at this point of time in step S**5**, the oil shortage state of compressor **1** is still continued. Hence, in order to compensate for the insufficiency of the refrigeration oil, controller **30** proceeds the process to a step S**6** to open electromagnetic valve **7**, thereby starting to return the oil from oil separator **2**. Then, after waiting for passage of a predetermined time in a step S**7**, controller **30** closes electromagnetic valve **7** in a step S**8** to end the oil returning.

In the above-described control, the oil is returned from accumulator **6** located at a downstream side of the refrigerant circuit and then the oil is returned, if the amount of the oil is insufficient, from the oil separator located at the upstream side. This is due to the following reason: since the pressure of oil separator **2** at the upstream side is higher than that of accumulator **6**, energy loss can be reduced by returning the oil from accumulator **6** first.

Further, the oil level can be detected without an influence of the flow of the refrigerant because self-heating sensor **91**E is attached and mounted on the container using the parallel electrodes, i.e., because element **25** is disposed between two electrodes **23** and **24** disposed in parallel.

Second Embodiment

In the first embodiment, the oil level in compressor **1** is detected and the refrigeration oil is returned from oil separator **2** and accumulator **6**; however, in a second embodiment below, the following describes an example in which oil returning control is performed when one self-heating sensor is attached in oil separator **2**.

FIG. **5** is an entire configuration diagram of a refrigeration cycle apparatus according to the second embodiment. Refrigeration cycle apparatus **101** of FIG. **5** includes a sensor **92**F instead of sensor **91**E and a controller **31** instead of controller **30** in the configuration of refrigeration cycle apparatus **100** shown in FIG. **1**. Configurations of the other portions of refrigeration cycle apparatus **101** are the same as those of refrigeration cycle apparatus **100**. Moreover, the configuration and characteristics of sensor **92**F are the same as those of sensor **91**E shown in FIG. **2** and FIG. **3**.

Refrigeration cycle apparatus **101** of FIG. **5** includes a refrigerant circuit in which compressor **1**, oil separator **2**, condenser **3**, expansion valve **4**, evaporator **5**, and accumulator **6** are connected in this order. Oil separator **2** and accumulator **6** are connected to compressor **1** via oil returning paths **21**, **22**. Electromagnetic valves **7**, **8** are disposed on oil returning paths **21**, **22** respectively. One self-heating sensor **92**F is attached to oil separator **2**.

From the oil-mixed refrigerant discharged from compressor **1**, the refrigeration oil and the refrigerant are separated by a separation mechanism of oil separator **2**. The separated refrigeration oil is stored at the bottom portion of the casing of oil separator **2**.

FIG. **6** is a flowchart for illustrating oil returning control in the second embodiment. Hereinafter, a "step S**11**" or the like will be simply described as "S**11**" or the like. When self-heating sensor **92**F in oil separator **2** is soaked in the refrigeration oil as a result of accumulation of the refrigeration oil with passage of time and the output of self-heating sensor **92**F indicates oil voltage Vso (YES in S**11**), it is understood that compressor **1** is in the oil shortage state because the amount of accumulation of the refrigeration oil in oil separator **2** has been increased. Then, controller **31** opens electromagnetic valve **7** disposed on oil returning path **21** that connects oil separator **2** to compressor **1** (S**12**), thereby starting to return the oil from oil separator **2** to compressor **1**. Then, controller **31** waits (NO in S**13**) for passage of a predetermined time calculated in consideration of an amount of oil brought out from compressor **1**, the oil separation efficiency of oil separator **2**, and the volume of each portion in the refrigerant circuit. After passage of the predetermined time (YES in S**13**), controller **31** closes electromagnetic valve **7** (S**14**) to end the oil returning.

Moreover, when the output of sensor **92**F does not indicate oil voltage Vso (NO in S**11**), after passage of a predetermined time (YES in S**15**), controller **31** opens electromagnetic valve **8** to actively start returning the oil from accumulator **6** to compressor **1** (S**16**). In this way, the oil is returned to compressor **1** whenever at least the predetermined time passes, thus preventing the amount of accumulation of the oil in accumulator **6** from being increased too much. Then, controller **31** waits for passage of a predetermined time (NO in S**17**). After passage of the predetermined time (YES in S**17**), controller **31** closes electromagnetic valve **8** (S**18**), thereby ending the oil returning.

Third Embodiment

FIG. **7** is an entire configuration diagram of a refrigeration cycle apparatus according to a third embodiment. A refrigeration cycle apparatus **102** shown in FIG. **7** performs oil returning control in a manner in which the first embodiment and the second embodiment are combined. Refrigeration cycle apparatus **102** of FIG. **7** includes a sensor **92**F in addition to sensor **91**E and a controller **32** instead of controller **30** in the configuration of refrigeration cycle apparatus **100** shown in FIG. **1**. Refrigeration cycle apparatus **102** includes self-heating sensors **91**E, **92**F respectively attached to compressor **1** and oil separator **2**. Refrigeration cycle apparatus **102** includes a refrigerant circuit in which compressor **1**, oil separator **2**, condenser **3**, expansion valve **4**, evaporator **5**, and accumulator **6** are connected in this order. Oil separator **2** and accumulator **6** are connected to the compressor via oil returning paths **21**, **22**. Electromagnetic valves **7**, **8** are disposed on oil returning paths **21**, **22** respectively. Self-heating sensor **91**E is attached to the low shell portion of compressor **1**, and self-heating sensor **92**F is attached to oil separator **2**.

FIG. **8** is a flowchart for illustrating oil returning control in the third embodiment. With reference to FIG. **7** and FIG. **8**, when the output of self-heating sensor **91**E in compressor **1** indicates gas voltage Vsg (YES in S**21**), compressor **1** is in the oil shortage state. Then, controller **32** opens electromagnetic valve **8** on oil returning path **22** (S**22**), thereby returning the oil from accumulator **6** to compressor **1**. After passage of a predetermined time from the start of the oil returning (YES in S**23**), electromagnetic valve **8** is closed (S**24**). When the output of sensor **91**E indicates gas voltage Vsg at this point of time (YES in S**25**), the oil shortage state of compressor **1** is still continued. In order to compensate for the insufficiency of the refrigeration oil, electromagnetic valve **7** is opened to start returning the oil from oil separator **2** to compressor **1** (S**26**). After passage of a predetermined time (YES in S**27**), electromagnetic valve **7** is closed (S**28**) to end the oil returning.

On the other hand, when the output of sensor **91**E does not indicate gas voltage Vsg (NO in S**21**), compressor **1** is not in the oil shortage state. However, when the output of sensor **92**F indicates oil voltage Vso (YES in S**29**), the oil level of oil separator **2** has been increased, so that in order to lower the oil level, controller **32** opens electromagnetic valve **7** to start returning the oil actively from oil separator **2** to compressor **1** (S**30**). After passage of a predetermined time (YES in S**31**), controller **32** closes electromagnetic valve **7** (S**32**) to end the oil returning.

In the refrigeration cycle apparatus shown in the third embodiment, the oil shortage state in compressor **1** is detected by self-heating sensor **91**E attached to compressor **1**, whereas self-heating sensor **92**F is also attached to oil separator **2** to detect accumulation of the refrigeration oil in oil separator **2**. The refrigeration oil accumulated in oil separator **2** is returned actively. By performing the control in this way, the oil shortage state of compressor **1** can be reduced and the reliability of the refrigeration cycle apparatus can be secured. Moreover, during the oil returning, the oil returning from accumulator **6** having a low-pressure and low-temperature environment is performed prior to the oil returning from oil separator **2** having a high-temperature and high-pressure environment, whereby performance can be prevented from being decreased due to heat loss.

Fourth Embodiment

In each of the configurations shown in FIG. **1** and FIG. **7**, self-heating sensor **91**E is disposed at the low shell portion of compressor **1**, which corresponds to the necessary minimum height (critical oil level position) for protection of compressor **1**; however, in a fourth embodiment, the following describes a case where a self-heating sensor is disposed between the low shell portion and the motor of compressor **1**.

FIG. **9** is an entire configuration diagram of a refrigeration cycle apparatus according to the fourth embodiment. A refrigeration cycle apparatus **103** shown in FIG. **9** includes a refrigerant circuit in which compressor **1**, oil separator **2**, condenser **3**, expansion valve **4**, evaporator **5**, and accumulator **6** are connected in this order. Oil separator **2** and accumulator **6** are connected to compressor **1** via oil returning paths **21**, **22**. Electromagnetic valves **7**, **8** are disposed on oil returning paths **21**, **22** respectively. Between the low shell portion and the motor of compressor **1**, one self-heating sensor **91**M is attached. Controller **33** opens and closes electromagnetic valves **7**, **8** to respectively return the oil from oil separator **2** and accumulator **6** to compressor **1**.

FIG. **10** is a flowchart for illustrating oil returning control in the fourth embodiment. With reference to FIG. **9** and FIG. **10**, when the output of self-heating sensor **91**M in compressor **1** indicates gas voltage Vsg (YES in S**41**), compressor **1** has become close to the oil shortage state. Then, controller **33** opens electromagnetic valve **8** on oil returning path **22**, thereby returning the oil from accumulator **6** to compressor **1** (S**42**). After passage of a predetermined time (YES in S**43**), controller **33** closes electromagnetic valve **8** (S**44**). When the output of sensor **91**M indicates gas voltage Vsg at this point of time (YES in S**45**), the state close to the oil shortage of compressor **1** is still continued. In order to compensate for the insufficiency of the refrigeration oil, controller **33** opens electromagnetic valve **7** to start returning the oil from oil separator **2** to compressor **1** (S**46**). After passage of the predetermined time (YES in S**47**), controller **33** closes electromagnetic valve **7** to end the oil returning (S**48**).

Fifth Embodiment

FIG. **11** is an entire configuration diagram of a refrigeration cycle apparatus according to a fifth embodiment. In the configuration of refrigeration cycle apparatus **103** shown in FIG. **9**, a refrigeration cycle apparatus **104** shown in FIG. **11** includes: self-heating sensor **91**M disposed between the low shell portion and motor **10** of compressor **1**; self-heating sensor **92**F disposed in oil separator **2**; and a controller **34** instead of controller **33**. Refrigeration cycle apparatus **104** includes a refrigerant circuit in which compressor **1**, oil separator **2**, condenser **3**, expansion valve **4**, evaporator **5**, and accumulator **6** are connected in this order. Oil separator **2** and accumulator **6** are connected to compressor **1** via oil returning paths **21**, **22**. Electromagnetic valves **7**, **8** are disposed on oil returning paths **21**, **22** respectively. Between the low shell portion and the motor of compressor **1**, self-heating sensor **91**M is attached. Self-heating sensor **92**F is attached to oil separator **2**. Controller **34** opens and closes electromagnetic valves **7**, **8** to respectively return the oil from oil separator **2** and accumulator **6** to compressor **1**.

FIG. **12** is a flowchart for illustrating oil returning control in the fifth embodiment. With reference to FIG. **11** and FIG. **12**, when the output of self-heating sensor **91**M in compressor **1** indicates gas voltage Vsg (YES in S**51**), controller **34** opens electromagnetic valve **8** on oil returning path **22** to return the oil from accumulator **6** to compressor **1** (S**52**). After passage of a predetermined time (YES in S**53**), controller **34** closes electromagnetic valve **8** (S**54**). When the output of sensor **91**M indicates gas voltage Vsg at this point of time (YES in S**55**), controller **34** opens electromagnetic valve **7** to start returning the oil from oil separator **2** to compressor **1** (S**56**). After passage of a predetermined time (YES in S**57**), controller **34** closes electromagnetic valve **7** to end the oil returning (S**58**).

On the other hand, when the output of sensor **91**M does not indicate gas voltage Vsg (NO in S**51**), compressor **1** is not in the oil shortage state. However, when the output of sensor **92**F indicates oil voltage Vso (YES in S**59**), the oil level of oil separator **2** has been increased, so that in order to lower the oil level, controller **34** opens electromagnetic valve **7** to start returning the oil actively from oil separator **2** to compressor **1** (S**60**). After passage of a predetermined time (YES in S**61**), controller **34** closes electromagnetic valve **7** (S**62**) to end the oil returning.

In the fifth embodiment above, self-heating sensor **91**M is disposed between the critical oil level position (low shell portion) and motor **10** of compressor **1**, and the oil returning is started always at a position higher than the critical oil level position. Therefore, compressor **1** is not brought into the oil shortage state, thus achieving an effect of securing reliability by the oil returning control employing electromagnetic valves **7**, **8**. The oil returning mechanism of the fifth embodiment is more excellent than that of the first embodiment in terms of the prevention of oil shortage.

Sixth Embodiment

In the configuration shown in FIG. **5**, one self-heating sensor **92**F is attached to oil separator **2**; however, in a sixth embodiment, the following describes a case where a plurality of sensors are attached to oil separator **2**.

FIG. **13** is an entire configuration diagram of a refrigeration cycle apparatus according to the sixth embodiment. In the configuration of refrigeration cycle apparatus **101** shown in FIG. **5**, a refrigeration cycle apparatus **105** shown in FIG. **13** includes: self-heating sensor **92**F disposed in oil separator **2**; a self-heating sensor **92**E disposed at a lower portion of oil separator **2**: and a controller **35** instead of controller **31**. Refrigeration cycle apparatus **105** includes a refrigerant circuit in which compressor **1**, oil separator **2**, condenser **3**, expansion valve **4**, evaporator **5**, and accumulator **6** are connected in this order. Oil separator **2** and accumulator **6** are connected to compressor **1** via oil returning paths **21**, **22**. Electromagnetic valves **7**, **8** are disposed on oil returning paths **21**, **22** respectively. The two sensors (self-heating sensor **92**F and self-heating sensor **92**E) are attached to oil separator **2**. Controller **35** opens and closes electromagnetic valves **7**, **8** to respectively return the oil from oil separator **2** and accumulator **6** to compressor **1**.

FIG. **14** is a flowchart for illustrating oil returning control in the sixth embodiment. With reference to FIG. **13** and FIG. **14**, when the output of self-heating sensor **92**F disposed at the upper portion in oil separator **2** indicates gas voltage Vsg (YES in S**71**), controller **35** opens electromagnetic valve **7** on oil returning path **21** to start returning the oil from oil separator **2** (S**72**). When the output of self-heating sensor **92**E at the lower portion of oil separator **2** indicates gas voltage Vsg (YES in S**73**), it is found that a predetermined amount of the oil has been returned from oil separator **2** to compressor **1**. Then, controller **35** closes electromagnetic valve **7** to end the oil returning (S**74**). Moreover, even when the output of sensor **92**F does not indicate oil voltage Vso (NO in S**71**), after passage of a predetermined time (YES in S**75**), controller **35** opens electromagnetic valve **8** to start returning the oil actively (S**76**). Accordingly, the amount of the oil accumulated in accumulator **6** can be prevented from being increased too much. After passage of a predetermined time (YES in S**77**), controller **35** closes electromagnetic valve **7** to end the oil returning (S**78**).

Seventh Embodiment

Next, the following describes an embodiment in which self-heating sensors are disposed not only in oil separator **2** but also at the low shell portion of compressor **1** in the configuration of FIG. **13**.

FIG. **15** is an entire configuration diagram of a refrigeration cycle apparatus according to a seventh embodiment. In the configuration of refrigeration cycle apparatus **105** shown in FIG. **13**, a refrigeration cycle apparatus **106** shown in FIG. **15** includes: self-heating sensors **92**F, **92**E disposed in oil separator **2**; self-heating sensor **91**E disposed at the low shell portion of compressor **1**; and a controller **36** instead of controller **35**. Refrigeration cycle apparatus **106** includes a refrigerant circuit in which compressor **1**, oil separator **2**, condenser **3**, expansion valve **4**, evaporator **5**, and accumulator **6** are connected in this order. Oil separator **2** and accumulator **6** are connected to compressor **1** via oil returning paths **21**, **22**. Electromagnetic valves **7**, **8** are disposed on oil returning paths **21**, **22** respectively. Self-heating sensor **91**E is attached to the low shell portion of compressor **1**. Self-heating sensors **92**F, **92**E are attached to oil separator **2**. Controller **35** opens and closes electromagnetic valves **7**, **8** to respectively return the oil from oil separator **2** and accumulator **6** to compressor **1**.

FIG. **16** is a flowchart for illustrating oil returning control in the seventh embodiment. With reference to FIG. **15** and FIG. **16**, when the output of self-heating sensor **91**E in compressor **1** indicates gas voltage Vsg (YES in S**81**), compressor **1** is in the oil shortage state. Then, by opening electromagnetic valve **8** on oil returning path **22**, the oil starts to be returned from accumulator **6** (S**82**). After passage of a predetermined time (YES in S**83**), electromagnetic valve **8** is closed (S**84**). When the output of sensor **91**E indicates gas voltage Vsg at this point of time (YES in step S**85**), the oil shortage state of compressor **1** is still continued. In order to compensate for the insufficiency of the refrigeration oil, electromagnetic valve **7** is opened to start returning the oil from oil separator **2** (S**86**). When the output of sensor **92**E indicates gas voltage Vsg (YES in S**87**), it is found that the discharging of the refrigeration oil from oil separator **2** has been completed, so that controller **36** closes electromagnetic valve **7** to end the oil returning (S**88**).

On the other hand, when the output of sensor **91**E does not indicate gas voltage Vsg (NO in S**81**), compressor **1** is not in the oil shortage state. However, when the output of sensor **92**F indicates oil voltage Vso (YES in S**89**), the oil level of oil separator **2** has been increased, so that in order to lower the oil level, controller **36** opens electromagnetic valve **7** to start returning the oil actively from oil separator **2** to compressor **1** (S**90**). After the output of sensor **92**E indicates gas voltage Vsg (YES in S**91**), controller **36** closes electromagnetic valve **7** to end the oil returning (S**92**).

In refrigeration cycle apparatus **106** shown in the seventh embodiment, the oil shortage state in compressor **1** is detected by self-heating sensor **91**E attached in compressor **1**, whereas self-heating sensors **92**F, **92**E are attached also in oil separator **2** so as to actively return the refrigeration oil accumulated in oil separator **2**, whereby the oil shortage state of compressor **1** can be reduced and the reliability can be secured. By determining to end the oil returning using lower sensor **92**E of oil separator **2**, only the refrigeration oil can be accurately returned, thereby preventing the refrigerator performance from being decreased due to a reduced refrigerant flow rate. Refrigeration cycle apparatus **106** is more excellent than the configuration shown in FIG. **1** in that the performance can be prevented from being decreased by returning also the refrigerant during the oil returning.

Eighth Embodiment

Each of the configurations shown in FIG. **1**, FIG. **7**, FIG. **9**, FIG. **1**, and FIG. **15** is directed to an embodiment in which at least one self-heating sensor **91**E or **91**M is provided in compressor **1**; however, in an eighth embodiment, the following describes an oil returning mechanism when a plurality of sensors are attached to compressor **1**.

FIG. **17** is an entire configuration diagram of a refrigeration cycle apparatus according to the eighth embodiment. In the configuration of refrigeration cycle apparatus **102** shown in FIG. **7**, a refrigeration cycle apparatus **107** shown in FIG. **17** includes: self-heating sensor **92**F disposed in oil separator **2**; self-heating sensor **91**E disposed at the low shell portion of compressor **1**; self-heating sensor **91**F disposed at the motor position of compressor **1**; and a controller **37** instead of controller **32**. Refrigeration cycle apparatus **107** includes a refrigerant circuit in which compressor **1**, oil separator **2**, condenser **3**, expansion valve **4**, evaporator **5**, and accumulator **6** are connected in this order. Oil separator **2** and accumulator **6** are connected to compressor **1** via oil returning paths **21**, **22**. Electromagnetic valves **7**, **8** are disposed on oil returning paths **21**, **22** respectively. Sensor **91**E is attached to the low shell portion of compressor **1**, which corresponds to the critical oil level position. Moreover, sensor **91**F is attached to the motor position of compressor **1**. Moreover, self-heating sensor **92**F is attached to oil separator **2**.

FIG. **18** is a flowchart for illustrating oil returning control in the eighth embodiment. With reference to FIG. **17** and FIG. **18**, when the output of self-heating sensor **91**E in compressor **1** indicates gas voltage Vsg (YES in S**101**), compressor **1** is in the oil shortage state. Then, controller **37** opens electromagnetic valve **8** on oil returning path **22**, thereby returning the oil from accumulator **6** to compressor **1** (S**102**). After passage of a predetermined time (YES in S**103**), the refrigeration oil accumulated in accumulator **6** is released from accumulator **6**. Hence, controller **37** closes electromagnetic valve **8** (S**104**). When the output of sensor **91**E indicates gas voltage Vsg at this point of time (YES in step S**105**), the oil shortage state of compressor **1** is still continued. In order to compensate for the insufficiency of the refrigeration oil, controller **37** opens electromagnetic valve **7** to start returning the oil from oil separator **2** to compressor **1** (S**106**). When the output of sensor **91**F indicates oil voltage Vso (YES in S**107**) or after passage of a predetermined time (YES in S**108**), controller **37** closes electromagnetic valve **7** to end the oil returning (S**109**).

On the other hand, when the output of sensor **91**E does not indicate gas voltage Vsg (NO in S**101**), compressor **1** is not in the oil shortage state. However, when the output of sensor **92**F indicates oil voltage Vso (YES in S**110**), the oil level of oil separator **2** has been increased. Thus, in order to lower the oil level, controller **37** opens electromagnetic valve **7** to start returning the oil actively (S**11**). After passage of the predetermined time (YES in S**112**), controller **37** closes electromagnetic valve **7** to end the oil returning (S**113**).

In the refrigeration cycle apparatus according to the eighth embodiment, the oil shortage state in compressor **1** is detected by self-heating sensor **91**E attached in compressor **1**, whereas self-heating sensor **92**F is also attached in oil separator **2** to detect accumulation of the refrigeration oil in oil separator **2**. The refrigeration oil accumulated in oil separator **2** is returned actively. By performing the control in this way, the oil shortage state of compressor **1** can be reduced and the reliability of the refrigeration cycle apparatus can be secured. Moreover, by determining the oil returning upper limit using self-heating sensor **91**F attached to the motor position of compressor **1**, the motor can be prevented from being soaked in the refrigeration oil, thereby avoiding the performance of the compressor from being decreased. The refrigeration cycle apparatus of the eighth embodiment is more excellent than the refrigeration cycle apparatus of the first embodiment in that the amount of the oil in compressor **1** can be prevented from being excessive and the volume efficiency of the compressor can be prevented from being decreased.

Ninth Embodiment

The configuration shown in FIG. **17** is directed to an embodiment in which self-heating sensors **91**E. **91**F are provided at the low shell portion and the motor position in compressor **1** and sensor **92**F is provided in oil separator **2**. On the other hand, in a ninth embodiment, the following describes an embodiment in which one self-heating sensor **91**M is provided at a position between the low shell portion and the motor in compressor **1**, one self-heating sensor **91**F is provided at the motor position in compressor **1**, and one sensor **92**F is disposed in oil separator **2**.

FIG. **19** is an entire configuration diagram of a refrigeration cycle apparatus according to the ninth embodiment. In the configuration of refrigeration cycle apparatus **107** shown in FIG. **17**, a refrigeration cycle apparatus **108** shown in FIG. **19** includes: a self-heating sensor **91**M instead of self-heating sensor **91**E; and a controller **38** instead of controller **37**.

Refrigeration cycle apparatus **108** includes a refrigerant circuit in which compressor **1**, oil separator **2**, condenser **3**, expansion valve **4**, evaporator **5**, and accumulator **6** are connected in this order. Oil separator **2** and accumulator **6** are connected to compressor **1** via oil returning paths **21**, **22**.

Electromagnetic valves **7**, **8** are disposed on oil returning paths **21**, **22** respectively. Self-heating sensor **91**M is attached to the position between the motor and the low shell portion corresponding to the critical oil level position in compressor **1**, and self-heating sensor **91**F is attached to the motor position of compressor **1**. Moreover, one self-heating sensor **92**F is attached to oil separator **2**.

FIG. **20** is a flowchart for illustrating oil returning control in the ninth embodiment. With reference to FIG. **19** and FIG. **20**, when the output of self-heating sensor **91**M in compressor **1** indicates gas voltage Vsg (YES in S**121**), compressor **1** has become close to the oil shortage state. Then, controller **38** opens electromagnetic valve **8** on oil returning path **22**, thereby returning the oil from accumulator **6** to compressor **1** (S**122**). After passage of a predetermined time (YES in S**123**), the refrigeration oil accumulated in accumulator **6** is released from accumulator **6**. Hence, controller **38** closes electromagnetic valve **8** (S**124**). When the output of sensor **91**M indicates gas voltage Vsg at this point of time (YES in S**125**), the state close to the oil shortage of compressor **1** is still continued. In order to compensate for the insufficiency of the refrigeration oil, controller **38** opens electromagnetic valve **7** to start returning the oil from oil separator **2** to compressor **1** (S**126**). When the output of sensor **91**F indicates oil voltage Vso (YES in S**107**) or after passage of a predetermined time (YES in S**108**), controller **38** closes electromagnetic valve **7** to end the oil returning (S**129**).

On the other hand, when the output of sensor **91**M does not indicate gas voltage Vsg (NO in S**121**), compressor **1** is not in the oil shortage state. However, when the output of sensor **92**F indicates oil voltage Vso (YES in S**130**), the oil level of oil separator **2** has been increased. Thus, in order to lower the oil level, controller **38** opens electromagnetic valve **7** to start returning the oil actively (S**131**). After passage of a predetermined time (YES in S**132**), controller **38** closes electromagnetic valve **7** to end the oil returning (S**133**).

In the refrigeration cycle apparatus according to the ninth embodiment, decrease in the oil-level in compressor **1** is detected at an early stage using self-heating sensor **91**M attached slightly above the lower portion in compressor **1** so as to return the oil from accumulator **6** and oil separator **2**. Meanwhile, self-heating sensor **92**F is attached also to oil separator **2** to actively return the refrigeration oil accumulated in oil separator **2**, thereby maintaining the oil level in compressor **1** to be always equal to or higher than the critical oil level. These make it possible to secure the reliability of the refrigeration cycle apparatus. Moreover, by determining the oil returning upper limit using self-heating sensor **91**F attached to the motor position of compressor **1**, the motor can be prevented from being soaked in the liquid, thereby avoiding the performance of compressor **1** from being decreased.

The refrigeration cycle apparatus of the ninth embodiment is more excellent than the refrigeration cycle apparatus of the first embodiment in that by preventing an excessive amount of oil in compressor **1**, the volume efficiency of the compressor can be avoided from being decreased and oil shortage can be prevented.

Tenth Embodiment

Next, the following describes an embodiment in which one self-heating sensor **91**M is provided between the low shell portion and the motor of compressor **1** and two sensors **92**F, **92**E are provided at the upper and lower sides of oil separator **2**.

FIG. **21** is an entire configuration diagram of a refrigeration cycle apparatus according to a tenth embodiment. A refrigeration cycle apparatus **109** shown in FIG. **21** includes a refrigerant circuit in which compressor **1**, oil separator **2**, condenser **3**, expansion valve **4**, evaporator **5**, and accumulator **6** are connected in this order. Oil separator **2** and accumulator **6** are connected to compressor **1** via oil returning paths **21**, **22**. Electromagnetic valves **7**, **8** are disposed on oil returning paths **21**, **22** respectively. Self-heating sensor **91**M is attached between the low shell portion and the motor portion of compressor **1**, and two self-heating sensors **92**F, **92**E are attached at the upper and lower sides of oil separator **2**.

FIG. **22** is a flowchart for illustrating oil returning control in the tenth embodiment. With reference to FIG. **21** and FIG. **22**, when the output of self-heating sensor **91**M in compressor **1** indicates gas voltage Vsg (YES in S**141**), compressor **1** is in a state close to oil shortage. Then, controller **39** opens electromagnetic valve **8** on oil returning path **22**, thereby returning the oil from accumulator **6** to compressor **1** (S**142**). After passage of a predetermined time (YES in S**143**), the refrigeration oil accumulated in accumulator **6** is released from accumulator **6**. Then, controller **39** closes electromagnetic valve **8** (S**144**). When the output of sensor **91**M indicates gas voltage Vsg at this point of time (YES in S**145**), compressor **1** is still continued to be in the state close to the oil shortage. In order to compensate for the insufficiency of the refrigeration oil, controller **39** opens electromagnetic valve **7** to start returning the oil from oil separator **2** to compressor **1** (S**146**). When sensor **92**E outputs the gas voltage (YES in S**147**), it is found that the release of the refrigeration oil stored in oil separator **2** has been completed. Then, controller **39** closes electromagnetic valve **7** to end the oil returning (S**148**).

On the other hand, when the output of sensor **91**M does not indicate gas voltage Vsg (NO in S**141**), compressor **1** is not in the oil shortage state. However, when the output of sensor **92**F indicates oil voltage Vso (YES in S**149**), the oil level of oil separator **2** has been increased, so that in order to lower the oil level, controller **39** opens electromagnetic valve **7** to start returning the oil actively (S**150**). When sensor **92**E outputs the gas voltage and the amount of oil in oil separator **2** is decreased (YES in S**151**), controller **39** closes electromagnetic valve **7** to end the oil returning (S**152**).

In the tenth embodiment, decrease in oil level in compressor **1** is detected by self-heating sensor **91**M attached slightly above the lower portion in compressor **1** to return the oil from accumulator **6** and oil separator **2**. Accordingly, the oil level in compressor **1** is always maintained to be above the critical oil level. Moreover, self-heating sensor **92**F is attached also to oil separator **2** to detect that the refrigeration oil has been accumulated in oil separator **2**. The refrigeration oil accumulated in oil separator **2** is returned actively. These make it possible to secure the reliability of the refrigeration cycle apparatus. Meanwhile, by determining to end the oil returning using sensor **92**E at the lower portion of oil separator **2**, it is possible to accurately return only the refrigeration oil, thereby preventing the refrigerator performance from being decreased due to a reduced refrigerant flow rate. The refrigeration cycle apparatus of the tenth embodiment is more excellent than the refrigeration cycle apparatus of the first embodiment in that: the refrigerator performance can be prevented from being decreased due to the refrigerant being returned together with the refrigeration oil during the oil returning; and the oil shortage can be prevented completely.

Eleventh Embodiment

In each of the above embodiments, it has been illustrated that at least one or at least two sensors were attached in compressor **1** and oil separator **2**. In the eleventh embodiment, the following describes an embodiment in which two sensors are provided in each of compressor **1** and oil separator **2**.

FIG. **23** is an entire configuration diagram of a refrigeration cycle apparatus according to the eleventh embodiment. Refrigeration cycle apparatus **110** shown in FIG. **23** includes a refrigerant circuit in which compressor **1**, oil separator **2**, condenser **3**, expansion valve **4**, evaporator **5**, and accumulator **6** are connected in this order. Oil separator **2** and accumulator **6** are connected to compressor **1** via oil returning paths **21**, **22**. Electromagnetic valves **7**, **8** are disposed on oil returning paths **21**, **22** respectively. Self-heating sensor **91**E is provided at the low shell portion of compressor **1**, and self-heating sensor **91**F is provided at the motor position of compressor **1**. Moreover, two upper and lower self-heating sensors **92**F, **92**E are attached to oil separator **2**.

FIG. **24** is a flowchart for illustrating oil returning control in the eleventh embodiment. With reference to FIG. **23** and FIG. **24**, when the output of self-heating sensor **91**E in compressor **1** indicates gas voltage Vsg (YES in S**161**), compressor **1** is in the oil shortage state. Then, controller **40** opens electromagnetic valve **8** on oil returning path **22**, thereby returning the oil from accumulator **6** to compressor **1** (S**162**). After passage of a predetermined time (YES in S**163**), the refrigeration oil accumulated in accumulator **6** is released from accumulator **6**. Then, controller **40** closes electromagnetic valve **8** (S**164**). When the output of sensor **91**E indicates gas voltage Vsg at this point of time (YES in S**165**), the oil shortage state of compressor **1** is still continued. In order to compensate for the insufficiency of the refrigeration oil, controller **40** opens electromagnetic valve **7** to start returning the oil from oil separator **2** to compressor **1** (S**166**). When the output of sensor **91**F indicates oil voltage Vso (YES in S**167**) or when the output of sensor **92**E indicates gas voltage Vsg (YES in S**168**), controller **40** closes electromagnetic valve **7** to end the oil returning (S**169**).

On the other hand, when the output of sensor **91**E does not indicate gas voltage Vsg (NO in S**161**), compressor **1** is not in the oil shortage state. However, when the output of sensor **92**F indicates oil voltage Vso (YES in S**170**), the oil level of oil separator **2** has been increased, so that in order to lower the oil level, controller **40** opens electromagnetic valve **7** to start returning the oil actively (S**171**). When the output of sensor **91**F indicates oil voltage Vso (YES in S**172**) or when sensor **92**E outputs gas voltage and the amount of oil accumulated in oil separator **2** has been decreased (YES in S**173**), controller **40** closes electromagnetic valve **7** to end the oil returning (S**174**).

In the eleventh embodiment, the oil shortage state in compressor **1** is detected by self-heating sensor **91**E attached to the lower portion in compressor **1** and the oil is returned from accumulator **6** and oil separator **2**. On the other hand, self-heating sensor **92**F is attached also to oil separator **2** to detect that the refrigeration oil has been accumulated in oil separator **2**. The refrigeration oil accumulated in oil separator **2** is returned actively. By performing the control in this way, the oil shortage state of compressor **1** can be reduced and the reliability of the refrigeration cycle apparatus can be secured. Moreover, by determining the oil returning upper limit using self-heating sensor **91**F attached to the motor position of compressor **1**, the motor can be prevented from being soaked in the liquid, thereby avoiding the performance of compressor **1** from being decreased. Further, by determining to end the oil returning also using lower sensor **92**E in oil separator **2**, it is possible to accurately return only the refrigeration oil to the compressor, thereby preventing the refrigerator performance from being decreased due to a reduced refrigerant flow rate.

The eleventh embodiment is more excellent than the first embodiment in that the volume efficiency of compressor **1** can be avoided from being decreased due to an excessive amount of the oil in compressor **1** and the refrigerator performance can be prevented from being decreased due to the refrigerant being returned during the oil returning.

Twelfth Embodiment

In a twelfth embodiment, the following describes an embodiment in which one self-heating sensor is disposed at the position between the low shell portion and the motor of compressor **1**, one self-heating sensor is disposed at the motor position, and two self-heating sensors are disposed at the upper and lower sides of oil separator **2**.

FIG. **25** is an entire configuration diagram of a refrigeration cycle apparatus according to the twelfth embodiment. A refrigeration cycle apparatus **111** shown in FIG. **25** includes a refrigerant circuit in which compressor **1**, oil separator **2**, condenser **3**, expansion valve **4**, evaporator **5**, and accumulator **6** are connected in this order. Oil separator **2** and accumulator **6** are connected to compressor **1** via oil returning paths **21**, **22**. Electromagnetic valves **7**, **8** are disposed on oil returning paths **21**, **22** respectively. Self-heating sensor **91**M is provided between the low shell portion and the motor position of compressor **1**, and self-heating sensor **91**F is provided at the motor position of compressor **1**. Moreover, two upper and lower self-heating sensors **92**F, **92**E are attached at oil separator **2**.

FIG. **26** is a flowchart for illustrating oil returning control in the twelfth embodiment. With reference to FIG. **25** and FIG. **26**, when the output of self-heating sensor **91**M in compressor **1** indicates gas voltage Vsg (YES in S**181**), compressor **1** is in a state close to oil shortage. Then, controller **41** opens electromagnetic valve **8** on oil returning path **22**, thereby returning the oil from accumulator **6** to compressor **1** (S**182**). After passage of a predetermined time (YES in S**183**), the refrigeration oil accumulated in accumulator **6** is released from accumulator **6**. Then, controller **41** closes electromagnetic valve **8** (S**184**). When the output of sensor **91**M indicates gas voltage Vsg at this point of time (YES in S**185**), the state close to the oil shortage of compressor **1** is still continued. In order to compensate for the insufficiency of the refrigeration oil, controller **41** opens electromagnetic valve **7** to start returning the oil from oil separator **2** to compressor **1** (S**186**). When the output of sensor **91**F indicates oil voltage Vso (YES in S**187**) or when the output of sensor **92**E indicates gas voltage Vsg (YES in S**188**), controller **41** closes electromagnetic valve **7** to end the oil returning (S**189**).

On the other hand, when the output of sensor **91**M does not indicate gas voltage Vsg (NO in S**181**), compressor **1** is not in the oil shortage state. However, when the output of sensor **92**F indicates oil voltage Vso (YES in S**190**), the oil level of oil separator **2** has been increased, so that in order to lower the oil level, controller **41** opens electromagnetic valve **7** to start returning the oil actively (S**191**). When the output of sensor **91**F indicates oil voltage Vso (YES in S**192**) or when sensor **92**E outputs the gas voltage and the amount of oil accumulated in oil separator **2** has been decreased (YES in S**193**), controller **41** closes electromagnetic valve **7** to end the oil returning (S**194**).

In the twelfth embodiment, decrease in the oil level in the compressor is detected by self-heating sensor **91**M attached slightly above the lower portion in compressor **1** and the oil is returned from accumulator **6** and oil separator **2**. On the other hand, self-heating sensor **92**F is attached also to oil separator **2** to detect that the refrigeration oil has been accumulated in oil separator **2**. Then, the refrigeration oil accumulated in oil separator **2** is returned actively. By performing the control in this way, the oil shortage state in compressor **1** can be prevented completely and the reliability of the refrigeration cycle apparatus can be secured.

Moreover, by determining the oil returning upper limit using self-heating sensor **91**F attached to the motor position of compressor **1**, the motor can be prevented from being soaked in the liquid, thereby avoiding the performance of compressor **1** from being decreased. Further, by determining to end the oil returning using lower sensor **92**E in oil separator **2**, only the refrigeration oil can be accurately returned to compressor **1**, thereby preventing the refrigerator performance from being decreased due to a reduced refrigerant flow rate.

The twelfth embodiment is more excellent than the first embodiment in that: the volume efficiency of the compressor can be avoided from being decreased due to an excessive amount of the oil in compressor **1**: oil shortage can be completely prevented; and the refrigerator performance can be prevented from being decreased due to the refrigerant being returned during the oil returning.

Finally, the refrigeration cycle apparatuses according to the respective embodiments will be summarized with reference to the main figures again. Among the embodiments, each of refrigeration cycle apparatuses **100** to **111** is a refrigeration cycle apparatus in which refrigerant circulates in an order of a compressor **1**, an oil separator **2**, a condenser **3**, an expansion valve **4**, an evaporator **5**, and an accumulator **6**. Refrigeration cycle apparatus **100** includes: an oil returning path **21** extending from oil separator **2** to compressor **1**: an electromagnetic valve **7** provided on oil returning path **21**: an oil returning path **22** extending from accumulator **6** to compressor **1**: an electromagnetic valve **8** provided on oil returning path **22**; and a controller **30** to **41** configured to control a degree of opening of electromagnetic valve **7** and a degree of opening of electromagnetic valve **8**.

Refrigeration cycle apparatus **100** (or **103**) shown in FIG. **1** (or FIG. **9**) further includes a self-heating sensor **91**E (or **91**M) configured to detect an oil level position of refrigeration oil of compressor **1**. Controller **30** (or **33**) is configured to: increase the degree of opening of electromagnetic valve **8** when an output of self-heating sensor **91**E (or **91**M) indicates insufficiency of the refrigeration oil of compressor **1** at a first point of time; and increase the degree of opening of electromagnetic valve **7** when the output of self-heating sensor **91**E (or **91**M) indicates the insufficiency of the refrigeration oil of compressor **1** at a second point of time subsequent to the first point of time.

Since the self-heating sensor thus detects insufficiency of the refrigeration oil in compressor **1** precisely, oil shortage of compressor **1** can be prevented and performance of the refrigeration cycle apparatus can be prevented from being decreased due to an excess of oil.

Refrigeration cycle apparatus **107** (or **108**) shown in FIG. **17** (or FIG. **19**) further includes: a self-heating sensor **91**E (or **91**M) configured to detect that an oil level position of refrigeration oil of compressor **1** is below a first position; and a self-heating sensor **91**F configured to detect that the oil level position is above a second position higher than the first position. Controller **37** (or **38**) is configured to: increase the degree of opening of electromagnetic valve **8** when an output of self-heating sensor **91**E (or **91**M) indicates that the oil level position is below the first position at a first point of time; increase the degree of opening of electromagnetic valve **7** when the output of self-heating sensor **91**E (or **91**M) indicates that the oil level position is below the first position at a second point of time subsequent to the first point of time; and close electromagnetic valve **7** when an output of self-heating sensor **91**F indicates that the oil level position is above the second position.

Since the self-heating sensors thus precisely detect that the refrigeration oil in compressor **1** is insufficient and that the oil has been sufficiently returned to compressor **1**, oil shortage of compressor **1** can be prevented and performance of the refrigeration cycle apparatus can be prevented from being decreased due to an excess of oil.

Refrigeration cycle apparatus **101** shown in FIG. **5** further includes a self-heating sensor **92**F configured to detect an oil level position of refrigeration oil of oil separator **2**. Controller **31** is configured to increase the degree of opening of electromagnetic valve **7** when an output of self-heating sensor **92**F indicates that an amount of the refrigeration oil in oil separator **2** is increased to be more than a reference amount.

Since the self-heating sensor can thus precisely detect that the amount of oil in oil separator **2** has become close to the upper limit, the performance of oil separator **2** can be prevented from being decreased, and the refrigeration oil can be prevented from being brought into the refrigerant circuit, thereby preventing oil shortage of compressor **1**.

Refrigeration cycle apparatus **105** (or **106**) shown in FIG. **13** (or FIG. **15**) further includes: a self-heating sensor **92**F configured to detect that an oil level position of refrigeration oil of oil separator **2** is above a first position; and a self-heating sensor **92**E configured to detect that the oil level position is below a second position lower than the first position. Controller **35** (or **36**) is configured to: increase the degree of opening of electromagnetic valve **7** when an output of self-heating sensor **92**F indicates that the oil level position is above the first position at a first point of time; and close electromagnetic valve **7** when an output of self-heating sensor **92**E indicates that the oil level position is below the second position at a second point of time subsequent to the first point of time.

Since the self-heating sensors thus precisely detect that the amount of oil in oil separator **2** has become close to the upper limit and that the refrigeration oil has been released from oil separator **2**, pressure loss due to the oil being returned from oil separator **2** can be reduced as much as possible while preventing the performance of oil separator **2** from being decreased, whereby the efficiency of the refrigeration cycle apparatus can be prevented from being decreased.

Refrigeration cycle apparatus **107** (or **108**) shown in FIG. **17** (or FIG. **19**) further includes: a self-heating sensor **91**E (or **91**M) configured to detect that an oil level position of refrigeration oil of compressor **1** is below a first position; a self-heating sensor **91**F configured to detect that the oil level position of the refrigeration oil of compressor **1** is above a second position higher than the first position: and a self-heating sensor **92**F configured to detect that the oil level position of the refrigeration oil of oil separator **2** is above a third position. Controller **37** (or **38**) is configured to: increase the degree of opening of electromagnetic valve **8** when an output of self-heating sensor **91**E (or **91**M) indicates that the oil level position is below the first position at a first point of time; and increase the degree of opening of electromagnetic valve **7** when the output of self-heating sensor **91**E (or **91**M) indicates that the oil level position is below the first position at a second point of time subsequent to the first point of time. Controller **37** (or **38**) is configured to increase the degree of opening of electromagnetic valve **7** when an output of self-heating sensor **92**F indicates that the oil level position of the refrigeration oil of oil separator **2** is above the third position at a third point of time. Controller **37** (or **38**) is configured to close electromagnetic valve **7** when an output of self-heating sensor **91**F indicates that the oil level position is above the second position.

The self-heating sensors thus precisely detect that the amount of oil in oil separator **2** has become close to the upper limit, detect oil shortage of compressor **1**, and precisely detect that the amount of oil in compressor **1** has become close to the upper limit during the oil returning. Accordingly, while preventing the oil shortage in compressor **1**, the oil returning can be stopped before loss occurs due to an excess of oil in compressor **1**. Moreover, the oil separation performance of oil separator **2** can be maintained to prevent the refrigeration oil from being brought into the refrigerant circuit.

Refrigeration cycle apparatus **106** (or **109**) shown in FIG. **15** (or FIG. **21**) further includes: a self-heating sensor **91**E (or **91**M) configured to detect an oil level position of refrigeration oil of compressor **1**; a self-heating sensor **92**F configured to detect that the oil level position of the refrigeration oil of oil separator **2** is above a first position; and a self-heating sensor **92**E configured to detect that the oil level position of the refrigeration oil of oil separator **2** is below a second position lower than the first position. Controller **36** (or **39**) is configured to: increase the degree of opening of electromagnetic valve **8** when an output of self-heating sensor **91**E (or **91**M) indicates insufficiency of the refrigeration oil of compressor **1** at a first point of time; and increase the degree of opening of electromagnetic valve **7** when the output of self-heating sensor **91**E (or **91**M) indicates the insufficiency of the refrigeration oil of compressor **1** at a second point of time subsequent to the first point of time. Controller **36** (or **39**) is configured to increase the degree of opening of electromagnetic valve **7** when an output of self-heating sensor **92**F indicates that the oil level position of the refrigeration oil of oil separator **2** is above the first position at a third point of time. Controller **36** (or **39**) is configured to close electromagnetic valve **7** when an output of self-heating sensor **92**E indicates that the oil level position of the refrigeration oil of oil separator **2** is below the second position.

Thus, since the self-heating sensor precisely detects the oil shortage of compressor **1**, the oil returning can be started before occurrence of oil shortage. Moreover, since the self-heating sensor precisely detects that the amount of oil in oil separator **2** has become close to the upper limit and that the refrigeration oil has been released from oil separator **2**, pressure loss due to the oil being returned from oil separator **2** can be reduced as much as possible while preventing the performance of oil separator **2** from being decreased, whereby the efficiency of the refrigeration cycle apparatus can be prevented from being decreased.

Refrigeration cycle apparatus **110** (or **111**) shown in FIG. **23** (or FIG. **25**) further includes: a self-heating sensor **91**E (or **91**M) configured to detect that an oil level position of refrigeration oil of compressor **1** is below a first position: a self-heating sensor **91**F configured to detect that the oil level position of the refrigeration oil of compressor **1** is above a second position higher than the first position: a self-heating sensor **92**F configured to detect that an oil level position of the refrigeration oil of oil separator **2** is above a third position; and a self-heating sensor **92**E configured to detect that the oil level position of the refrigeration oil of oil separator **2** is below a fourth position lower than the third position. Controller **40** (or **41**) is configured to: increase the degree of opening of electromagnetic valve **8** when an output of self-heating sensor **91**E (or **91**M) indicates that the oil level position is below the first position at a first point of time: and increase the degree of opening of electromagnetic valve **7** when the output of self-heating sensor **91**E (or **91**M) indicates that the oil level position is below the first position at a second point of time subsequent to the first point of time. Controller **40** (or **41**) is configured to increase the degree of opening of electromagnetic valve **7** when an output of self-heating sensor **92**F indicates that the oil level position of the refrigeration oil of oil separator **2** is above the third position at a third point of time. Controller **40** (or **41**) is configured to close electromagnetic valve **7** when an output of self-heating sensor **91**F indicates that the oil level position is above the second position or when an output of self-heating sensor **92**E indicates that the oil level position of the refrigeration oil of oil separator **2** is below the fourth position.

Thus, the self-heating sensors precisely detect the oil shortage of compressor **1** and precisely detect that the amount of oil in compressor **1** has become close to the upper limit during the oil returning. Accordingly, while preventing the oil shortage in compressor **1**, the oil returning can be stopped before loss occurs due to an excess of oil in compressor **1**. Moreover, since the self-heating sensors precisely detect that the amount of oil in oil separator **2** has become close to the upper limit and that the refrigeration oil has been released from oil separator **2**, pressure loss due to the oil returning from oil separator **2** can be reduced as much as possible while preventing the performance of oil separator **2** from being decreased, whereby the efficiency of the refrigeration cycle apparatus can be prevented from being decreased.

As shown in FIG. **2** and the like, any one of self-heating sensors **91**E, **91**M, **91**F, **92**E, **92**F described above has a heating element **25** configured to generate heat when supplied with electric power, heating element **25** having a resistance value that changes in response to a temperature change. By thus using the heating element in direct contact with the refrigeration oil to detect the level, it can be precisely detected that the oil level has reached a predetermined level.

The embodiments disclosed herein are illustrative and non-restrictive in any respect. The scope of the present invention is defined by the terms of the claims, rather than the embodiments described above, and is intended to include any modifications within the scope and meaning equivalent to the terms of the claims.

REFERENCE SIGNS LIST

1: compressor; **2**: oil separator; **3**: condenser; **4**: expansion valve; **5**: evaporator; **5**F: evaporator fan; **6**: accumulator; **7**, **8**: electromagnetic valve; **91**E, **91**F, **91**M, **92**E, **92**F: sensor; **10**: motor; **11**: casing; **12**: scroll compressor; **21**, **22**: oil returning path; **23**, **24**: electrode; **25**: element; **30** to **41**: controller.

The invention claimed is:

1. A refrigeration cycle apparatus in which refrigerant circulates in an order of a compressor, a first oil separator, a condenser, an expansion valve, an evaporator, and a second oil separator, the refrigeration cycle apparatus comprising:

a first oil return path extending from the first oil separator to the compressor;

a first valve provided on the first oil return path;

a second oil return path extending from the second oil separator to the compressor;

a second valve provided on the second oil return path;

a controller configured to control a degree of opening of the first valve and a degree of opening of the second valve; and

a first detector configured to detect an oil level position of refrigeration oil of the compressor,

wherein the controller is configured to

open the second valve when an output of the first detector indicates insufficiency of the refrigeration oil of the compressor at a first point of time, and

open the first valve when the output of the first detector indicates the insufficiency of the refrigeration oil of the compressor at a second point of time subsequent to the first point of time,

wherein the refrigeration cycle apparatus further comprises:

a second detector configured to detect that the oil level position of the refrigeration oil of the first oil separator is above a first position; and

a third detector configured to detect that the oil level position of the refrigeration oil of the first oil separator is below a second position lower than the first position, and

wherein the controller is configured to

open the first valve when the output of the first detector does not indicate insufficiency of the refrigeration oil of the compressor at the first point of time and when the output of the second detector indicates that the oil level position of the refrigeration oil of the first oil separator is above the first position at the first point of time, and

close the first valve when an output of the third detector indicates that the oil level position of the refrigeration oil of the first oil separator is below the second position.

2. The refrigeration cycle apparatus according to claim **1**, wherein

the first detector has a first electrode, a second electrode, and a heating element configured to generate heat when supplied with electric power, the heating element having a resistance value that changes in response to a temperature change, and

the heating element is disposed between the first electrode and the second electrode.

3. The refrigeration cycle apparatus according to claim **1**, wherein

each of the first detector, the second detector, and the third detector has a first electrode, a second electrode, and a heating element configured to generate heat when supplied with electric power, the heating element having a resistance value that changes in response to a temperature change, and

the heating element is disposed between the first electrode and the second electrode.

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